Products of American Forests

UNITED STATES
DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FOREST PRODUCTS LABORATORY

AUGUST 1939

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PREPARATION of even this brief and generalized survey of the productivity of America's forests required the collection of information from many sources. In forming estimates of quantities of products, statistical data made public through the Bureau of the Census, the United States Tariff Commission, and other Government agencies were drawn upon freely. In the account given of certain uses of wood, helpful suggestions were derived from publications of the Comité International du Bois, Brussels, and the National Lumber Manufacturers' Association, Washington, D. C. The comprehensive work of Nelson C. Brown, Timber Products and Industries, proved useful as a reference and check. Likewise of interest and value in their fields were the books From Forest to Furniture, by M. H. Sherwood, and History of Papermaking in the United States, by Lyman H. Weeks.

Of writings consulted in regard to the less-considered items of the forest crop—fruits, nuts, medicinals, and the like—the following merit special acknowledgment: Food from Wild Plants, by W. N. Clute; Black Walnut for Timber and Nuts, by W. R. Mattoon and C. A. Reed; the files (now closed) of the American Nut Journal from 1922 to 1931; Folk Medicines, by W. W. and F. A. Barkley; Sassafras Voyage, by D. McConkey; and American Medicinal Barks, by A. Henkel.

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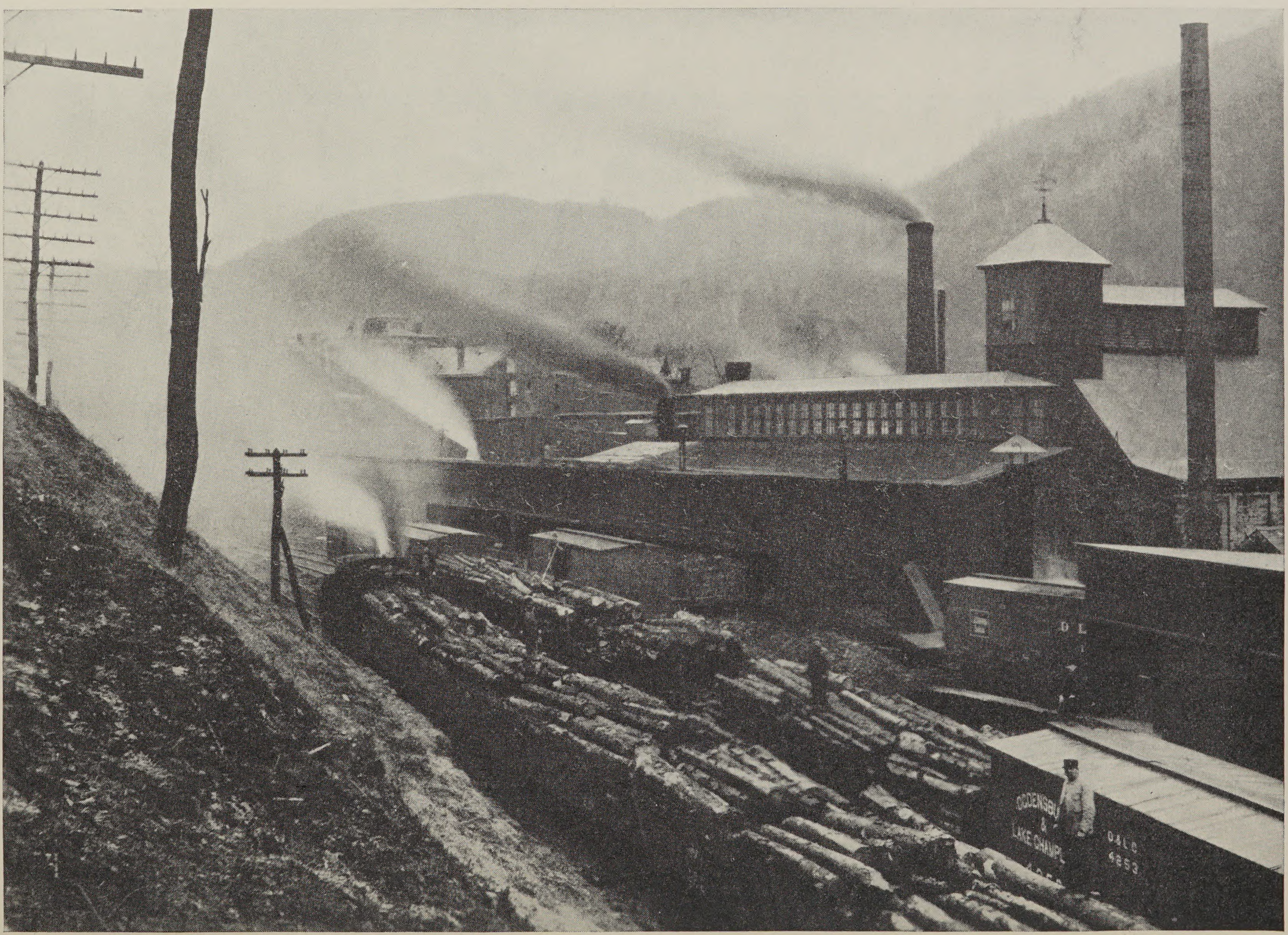

UNDERWOOD & UNDERWOOD

A great tide of raw materials flows from our forests through converting and fabricating industries.

Importance of Forest Resources

THE FOREST is a storehouse of wealth in the form of wood and other tree products of wide variety. So universal is the role of forest products in American economy that the description of them has occupied many writers and filled many books of technical information. The purpose of this publication, limited as it must be in detail, is simply to review the materials of the forest under certain broad classifications and to remind the reader of their manifold and varied adaptations to use. While the account is far from complete, particularly with regard to fabricated and manufactured articles of wood, examples are presented which outline the major types of utilization and throw some light on groups of products that are often overlooked.

From an early day the consumption of forest products in the United States has been on a scale unparalleled elsewhere. Forests supported the pioneers and built the Nation. They continue to pour out a great tide of essential economic goods. The gross market value of forest products in the United States prior to the depression, according to census figures for 1927 and 1929, was about 3½ billion dollars annually. Nearly 6 million of our people are directly supported by workers normally employed in lumber, pulp and paper, and other forest industries. Residential and building construction employs hundreds of thousands of men. The Nation's normal annual lumber requirement for construction and factory purposes has been estimated at about 30 billion board feet, not counting the enormous quantities of timber used in unsawed form and wood burned for fuel.

American building industries employ great numbers of workers.

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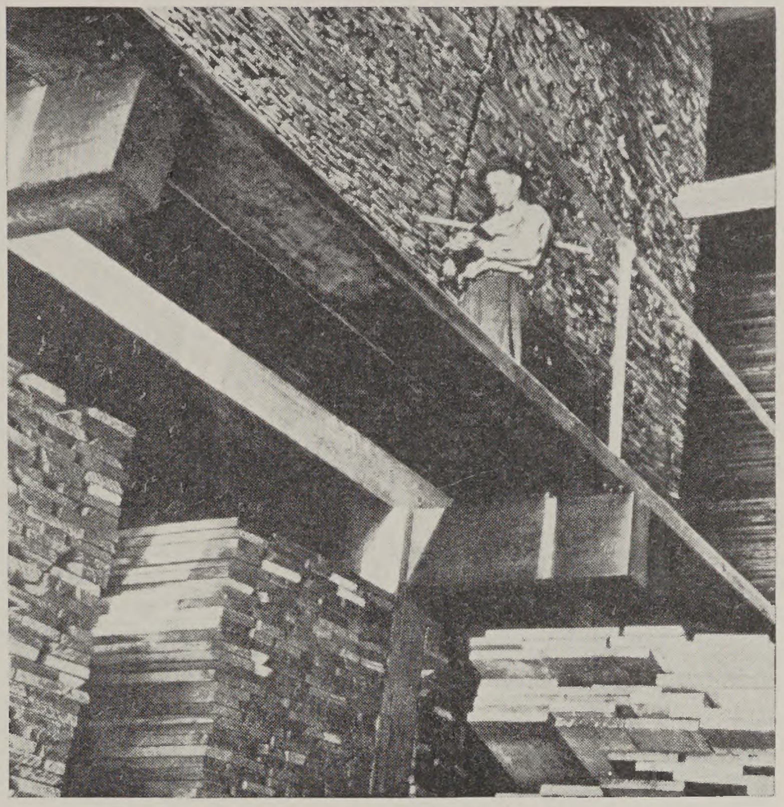


For construction and manufacture the United States requires each year billions of board feet of lumber.

Despite the important place of the forest in America's economic system, our tendency has been to take it largely for granted; to "mine" the timber rather than to "crop" it; to meet today's timber needs at the expense of tomorrow's; in other words, to expect perpetuation of the forest resources without the practice of forestry. Much of the land that yielded a rich bounty of timber has been left only partially productive. Far too much land on which a new timber crop might have brought profit to the owner and benefits to the community has lain idle and accumulated unpaid taxes, until finally its profitless burden has been shifted to county or State ownership. In many parts of the country decreasing timber production, receding land values, loss of employment and earning power, and declining tax revenues bear eloquent witness to the consequences of forest neglect.

Over against this toll of economic damage, modern forestry sets up the ideal of the forest as man's living

and permanent possession. Managed as a crop, the forest can renew itself and yield its wealth indefinitely, supporting the civilization that develops in and about it. The growing and harvesting of forest materials can and should provide steady employment and wages for a great army of workers. On this foundation the industrial community can establish itself securely, with dependable income to support homes and stable tax revenues to provide local government and needed public services.

Forests have general usefulness in keeping the land productive and habitable. They absorb rainfall and check excessive run-off, thus holding the soil against erosion, modifying the flow of natural waters, and protecting streams and lowlands against inundations of silt and debris. They mitigate destructive and drying winds. They provide habitat for birds, game, and fur-bearing animals, and they add beauty and interest to the land for the enjoyment of the home owner and the recreation seeker. Under a proper system of harvesting, the forest can render these essential services while yielding its regular contribution of products.

M5399F

Forestry yields a continuous crop of forest supplies while reserving a sufficient portion of the stand for growing stock.

Forestry as a productive and permanent system of land use is an integral part of agriculture, and agriculture has a major share in all its benefits. Within

Forestry often returns to the farmer his only cash crop.

M32606F

the sphere of forest influence the farmer's land is protected and his water supply safeguarded. Forest resources provide the farm family with building material, firewood, supplementary forage for livestock, and often a harvest of wild fruit, nuts, or the like. Forest industries and communities afford a local market for farm produce and opportunities for employment in off seasons. Productive forests and industries lighten the farm tax burden by sharing the expense and extending the advantages of schools and roads. In these and other ways a forest economy, while maintaining a due proportion of the land for its own use, promotes the prosperity of the rest of agriculture and rural life.

Answering to the Nation's forest needs is a total area of more than 600 million acres, nearly one-third of the continental United States, which is either in forest or suited by nature mainly or wholly to the growing of forests. The plans of forestry look forward to the replenishment, improvement, and realistic management of this vast resource. What is proposed is the restoration of a proper balance of land use in the United States, and work to that end is proceeding with a greater investment of money and man power than ever before in our history. It is a corrective and a constructive enterprise of momentous import to our future as a people.

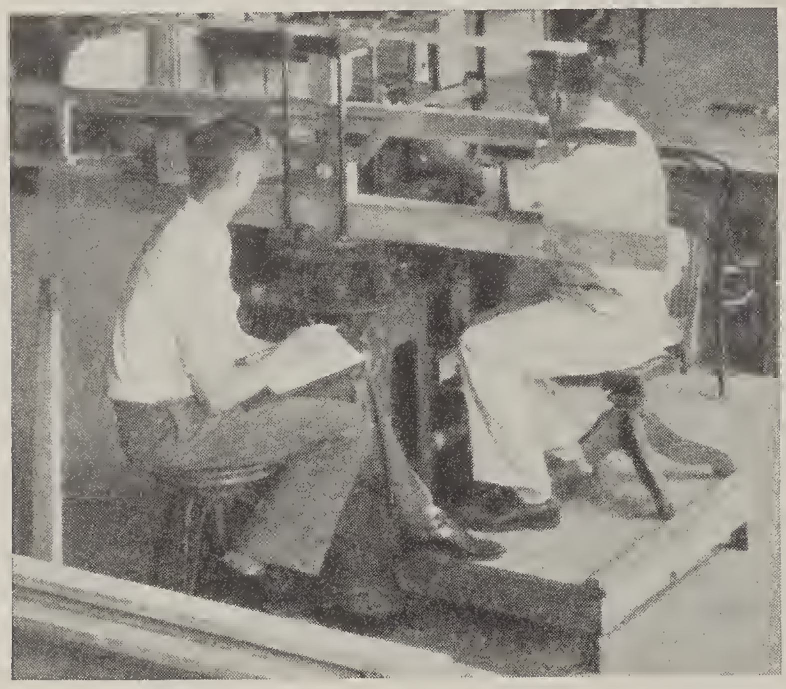
Utilization of Products is Essential

THE INTERESTS of economic forestry are concerned both with the growing of the forest crop and with its proper utilization. Although a number of the tree products enumerated in the following text found their greatest usefulness in an earlier stage of the country's development, there are vital needs that the forest continues to supply and that can hardly be expected to grow less as the country's population increases. The era of scarcity of natural resources is yet to be explored by the United States, but it has already been reached by many other nations. Their experience, if it were necessary to support the very convincing

Forest Products Laboratory, Madison, Wis. M31741F

evidence close at hand, clearly points to the wisdom of maintaining the forest and developing efficient means of utilizing materials that it supplies.

In countries of central and northern Europe, factories are already producing from wood food for man, fodder for cattle, and a substitute for wool in clothing. Shortages of liquid fuel for motors are beginning to be made up by the use of wood in the form of gas or alcohol, and scientists are busy in devising more efficient wood-burning stoves and furnaces for home and industrial use. Even pulping wastes are being requisitioned for their last ounce of sugar and tannin. Through these and similar developments, economic leaders are looking to the forest as a mainstay and support of economic existence.



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The adaptability of wood should be tested and proved against the most searching modern requirements.

So far as the United States is concerned, while such intensive utilization is not economically possible at present, it is nevertheless imperative to consider what the forest means to us today and what it may mean in our national future. We are still cutting saw timber several times as fast as it grows, and even cordwood perhaps twice as fast. Meanwhile, adequate and economical housing for the family of ordinary income still depends on wood as the cheapest material of proved adequacy. The United States has for years been importing pulpwood, pulp, and paper from abroad in vast quantities; yet the need for wood is leading to overcutting of forests in nearly all parts of the world. How soon the imports of pulp materials will be cut off will depend on the requirements and policies of other nations than our own. The United States is at present the greatest producer and also the most prodigal consumer of petroleum. Although our oil resources are still abundant, in the event of future shortage the development of other sources of motor fuel will be urgently required.

Such considerations as these emphasize the necessity of making the forest a permanent and productive part of our economy. Forest products may be of more vital service to the United States and to the world in the future than they have been in the past. The values at stake forbid that wood, the major forest material, should ever become outmoded and neglected. The United States, a Nation of forests, should continue to be amply served by the forest—in plentiful and economical housing, in needed furnishings, equipment and fuel, in abundant products of manufacture and chemical conversion, in industry and wages, and all that these things mean in a satisfactory scale of living.

The forest, unlike mineral resources, is potentially inexhaustible. The encroachment of other materials on fields of wood use is nothing more than the normal response of science and technology to the insistent modern demand for new and better products and services. Wood utilization likewise needs the increasing support of science to meet the modern challenge. Wood is an extremely adaptable material. Because of that very fact its adaptability should be tested and proved against the most searching requirements of the modern age. As with wood, so with other products of the forest—roots, bark, resins, extractives, and the rest. For the most part, the economic importance of forest products is not to be assessed in terms of past or even present markets, but by their inherent suitability to basic needs and their possibilities of adaptation to more exacting standards within their field.

Research in forest products is a definite part of forestry. It is concerned with increasing utilization values both to the forest grower and to the consumer, to the end that forest materials shall adequately meet the economic needs of the present and future. It has to do with the determination of properties and evaluation of quality of the material, the modification of properties in line with service requirements, the reduction of wastes and production costs, and the development of new and improved products. The research of the Forest Products Laboratory [1] represents the direct interest and participation of the Forest Service in this work of maintaining the utility and service value of the forest crop.

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

There is both scope and need for a great enlargement of the research effort. Compared with other major resources of the United States, the forest is still too largely a neglected asset with respect to the scientific development and adaptation of its products. Research, consistently prosecuted and applied, can be followed up to large practical gains in the improved quality, utility, and marketing of forest commodities of all kinds. By a sound development of its material values in accord with advancing service standards, forestry can look forward to the fulfillment of its largest objectives in the country's economic future. This is the forward view which gives intensified meaning and interest to the unfinished story of forest products in the United States.

Wood and Some of Its Primary Uses

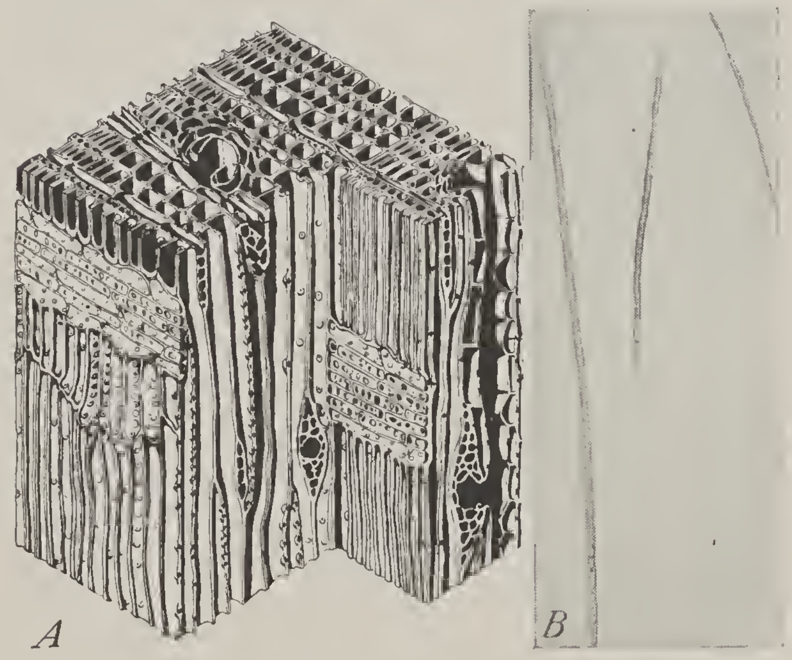
NATURE designed wood to function as the supply line and support of the tree. It happens that the processes of construction elaborated through long ages to suit wood for this fundamental purpose are well calculated also to make it one of the most useful materials at the disposal of mankind.

As a channel through which water and dissolved materials are drawn from the soil to feed the growing tree, wood is permeable to water longitudinally. Under the microscope a cross section of a piece of wood is seen to consist of separate units arranged in very close formation. These units are, for the most part, fibrous cells, narrow tubes about as fine as a human hair, whose walls are composed mostly of still finer spirally wound strands of cellulose. They are cemented together by a substance called lignin. The arrangement is intricate in its details and varies widely among the many species of trees. It is this variation that gives to woods of different species the properties that make them suitable for different uses.

Under the climatic influences of the temperate zone, new wood growth is added to the tree trunk in annual layers, which are seen as rings in cross section. In the life processes of the tree complex chemical substances are formed that vary again among species; often they are highly colored. The varied arrangement of fibers, growth layers, and coloring materials produces the attractive patterns and figured effects that give distinctive beauty to the sawed and finished surfaces of many woods.

An effective way to obtain strength combined with light weight is to make use of hollow tubes. That is what nature has done in the formation of wood. The tree must bear the heavy load of its own weight and must resist heavy wind pressure. Its trunk must therefore be strong yet sufficiently yielding to bend in a storm instead of breaking, and it must be elastic so that it will spring back to an erect position when the storm has passed. The hollow tubes of its supply line, the trunk, are mechanically adjusted to these several requirements according to the habit of the species. Thus wood is a material that is generally strong for its weight but diversified in species characteristics and thereby adapted to an amazing variety of uses.

An attempted census of the uses of wood once reached a count of 4,500 without even approaching a full and exhaustive classification. Wood has literally thousands of uses, satisfying essential needs and contributing constantly to man's comfort and convenience in matters both small and great. Toothpicks and telegraph poles, matchsticks and derrick booms, lowly mine timber and finest figured furniture—these merely suggest its wide



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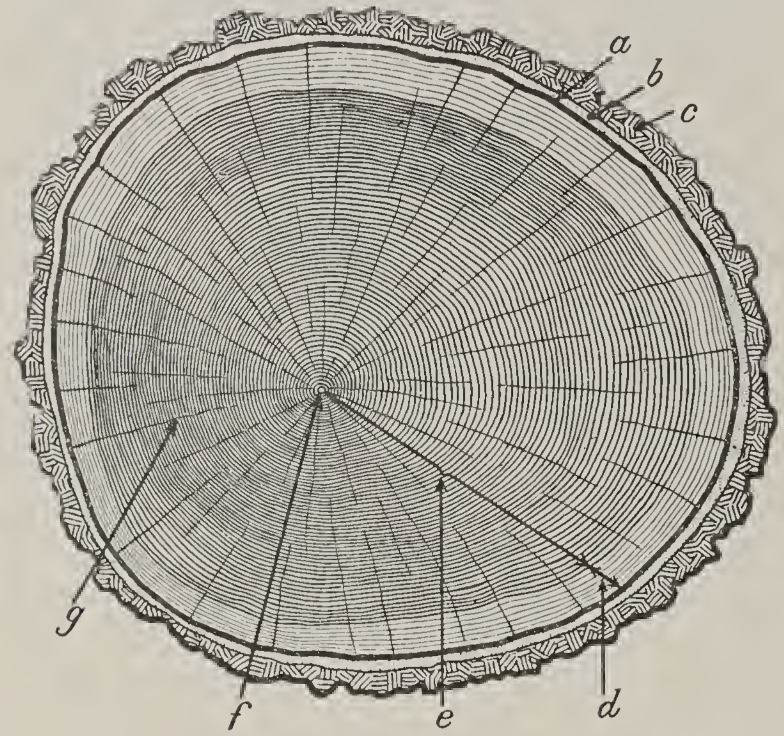
A, Wood is made up of long, narrow tubes, here shown magnified 60 diameters; B, fibrous cells of wood, each of about the fineness of a human hair (×10).

range of uses. From light, soft, weak willow to the heavy, hard, tough hickory or Osage-orange, almost any required level of properties can be found in our

native species, fitting them for a marvelous diversity of general and special services and promising increased usefulness under the guiding hand of science.

The processes by which wood is prepared for use are likewise varied. For many basic uses the simplest rugged implements are sufficient—ax, crosscut saw, adze, wedge, and maul. For others a tremendous array of specialized tools and mechanisms is in operation—high-speed band saws, lumber-handling appliances, the complete kit of carpentry and joinery, power lathes, planers, shapers, and sanders, nailing machines, stills and retorts, vats and pressure vessels, veneer cutters, apparatus for barking, grinding, shredding, and pulping, and the entire equipment of the paper-making and chemical conversion industries.



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Section of a tree trunk. The annual growth layers are clearly shown: a, Bark; b, phloem; c, cambium; d, sapwood; e, heartwood; f, pith; g, wood ray.

A freshly cut log or the trunk of a standing tree contains water in an amount from one-fourth to two-thirds or more of the total weight. Much lumber is used in the green condition, but for most purposes it must be seasoned. The water is removed by regulated drying operations in order to insure that the lumber will not shrink excessively in use. The dried lumber is usually planed smooth and is sorted and selected according to commercial standards of quality and use before being shipped to market.

House Construction.

The outstanding example of wood use in the United States is the homes it provides, especially those houses of moderate cost in which the majority of people live. Despite the development and steady promotion of new building materials, more than four-fifths of existing dwellings in the United States, occupied by 90 million people, are of all-wood construction. In a very large proportion of the rest, such major items as framework, floors, doors, and windows are of wood. Among small residences the house containing no wood has, until recently, been a curiosity. One may well inquire why wood should not continue to be the prime resource in the housing of the United States.

For a given amount of shelter and floor space, the home builder of moderate means generally finds that his needs can be met by wood more cheaply than by other construction materials. For the more expensive type of house, also, wood is often preferred on its merits—its adaptability and variety, its "homelike" character, and its natural insulating quality.

An objection often overemphasized is the hazard of fire of wood residential construction. The widespread adoption of restrictions on types of occupancies and the spacing of dwellings in residential sections has considerably reduced fire hazards. The fire problem of the modern single residence does not seriously militate against the use of wood from the standpoint of either insurability or practical safety. Wood treated with fire-retardant chemicals, either by impregnation or surface treatment, may be used at critical points as an additional precaution. While wood is, by nature, a combustible substance, a thorough treatment can make it sufficiently fire resistant so that it will not of itself support combustion. When the cost of such treatments has been reduced, many additional uses will be opened to wood for which noncombustible materials are now preferred.

M25643F

View of the Ralph Waldo Emerson house, Concord, ~~N. H.~~ Mass., taken in 1937. The house was old when purchased by Emerson more than 100 years ago.

Well-built houses of wood can resist strong winds. M15845F

It is rare indeed that a house completes its span of life without some modification in its structure. The size and needs of families change; houses change owners, architectural styles change, and tastes vary. A frame house can be remodelled at comparatively small expense. Much of the original material can be removed without endangering the strength of the structure, and, in adding new construction, wood is easy to fabricate and fasten in place.

Old-fashioned structures made use of timber in large sizes and wasteful amounts. A strongly built house does not require an excessive consumption of material. Wood has both tensile and compressive strength combined with resiliency or toughness. By taking full advantage of these characteristics, wood structures can be designed and built to withstand violent destructive forces of nature. A frame house, properly built, is the safest dwelling every devised at reasonable cost for an earthquake area. A well-built wood house is a strong, elastic, relatively light structure capable of taking shock distortion and returning to shape. When the earthquake is over, the foundation may be cracked, the chimney down, and the plaster off, but the wood frame, walls, and roof will be generally intact and ready for continued service with minimum expense for repairs.

Wood structures can be built with ample resistance to wind. Here adequate fastening together of all parts is especially important. A two-story frame house in Florida that withstood intact the full force of a recent major hurricane was an example of stout fastening; more than a ton of nails are said to have been used in its construction. Obviously, a building to resist wind pressure effectively must have walls of high resistance to bending. A house built of lumber should not be held in place by its weight alone but by bolts passing through the sills and imbedded deeply in the foundation. Joists, studding, plates, and rafters, firmly nailed to each other, make the building a unit in resisting expansive forces and suction that would otherwise force out walls or lift the roof. Walls are greatly strengthened against lateral distortion by diagonal sheathing, and diagonally laid subfloors likewise add rigidity to the house.

Dwelling houses must withstand the ravages of time. In this respect also wood may be relied on if properly selected and used. The Fairbanks house in Dedham, Mass., built of wood in 1636, is still standing, structurally intact, after three centuries. There are hosts of frame houses in the United States 100 years old and more. The White House, when remodelled in 1928, was found to contain sound roof timbers that had been in

place since 1816. Timbers have been found in the pueblos of the Southwest that are several hundred years old, and Europe can show numerous examples of timbered construction dating well back into the Middle Ages.

When timber in a house decays, it is usually because of faulty construction in which wood is exposed to dampness for long periods. Too often nondurable sapwood is exposed to conditions unsuited even to the most resistant heartwood. Virulent decay from such causes has been known to spread throughout the house and destroy it. In places where exposure to excessive moisture is inescapable, wood treated with a good preservative should be used. The durability record of wood will be largely improved as the relative value of preservatives becomes more widely known and satisfactorily treated material is made more generally available to the small user.

Much alarm has been caused recently by reports of heavy damage to wood in American homes wrought by termites or white ants. The danger from these pests has been greatly exaggerated. There is no "invasion"; authorities state that termites have probably always been here, capable of making inroads on wood when conditions are in their favor. Insistence upon properly installed corrosion-proof metal shields between the house and the foundation will prevent practically all damage from termites. In some cases, timber impregnated with preservative materials should be used as an additional safeguard.

In the interior of the house, in floors, doors, and finishing, wood has some of its most highly prized uses. To the warmth and resistance to wear of wooden floors are added the attractiveness of grain and pattern. The floor may be an economical but entirely suitable softwood, or it may be of hardwood laid in any arrangement from plain strips to the most elaborate parquetry, according to taste. In any case, proper selection, installation, and care of the wood will assure long and satisfactory service. The soft lighting of a polished wood floor enhances the beauty of well-chosen rugs and furnishings and adds dignity and charm to the home. In the case of baseboards, moldings, beams, and panelings, wood again offers a wide range of pattern and color that can harmonize with any scheme of decoration.

Window frames and sashes of wood continue to demonstrate their convenience and utility. With proper sealing devices, wood windows are weather-tight but easily operated. If misalignment occurs because of settling of the building, the wood sash is easily and quickly refitted so as to operate smoothly. Screens and storm windows can be accommodated without extra framing. The attractive appearance of wood windows from without, the depth of the shadows of their members, and the great variety of sizes and shapes in which they are available are additional factors that appeal to home builders.

Veneer and Plywood.

Veneer is wood cut in sheet form. Much of it, perhaps nearly half, is used in single thickness, as in the manufacture of baskets and boxes. In this important agricultural classification it is estimated that at least a billion square feet is used annually.

The remainder is utilized by gluing, either as an exterior facing for other wood or as a component part of layered pieces or panels. Its use as ornamental facing dates from more than 3,500 years ago, as is witnessed by an Egyptian tomb mural at Thebes from the era of Thotmes III, depicting veneer makers at their trade, and by specimens of cabinet work recovered from still earlier periods.

The use of veneers in fine furniture making flourished under the Roman Empire but virtually disappeared during the disorders of the Middle Ages. Beautiful wood inlays and surfacings were again produced in the time of the Renaissance in Italy, from whence the practice spread to France, Germany, and England and became an established part of modern craftsmanship. The masterpieces of Adam, Chippendale, and Sheraton exemplify the degree of manual skill employed in the use of fine veneers on a well-glued foundation of ordinary woods.

Rotary-cut or "peeled" veneer is made by rotating the log in a lathe against a heavy blade.

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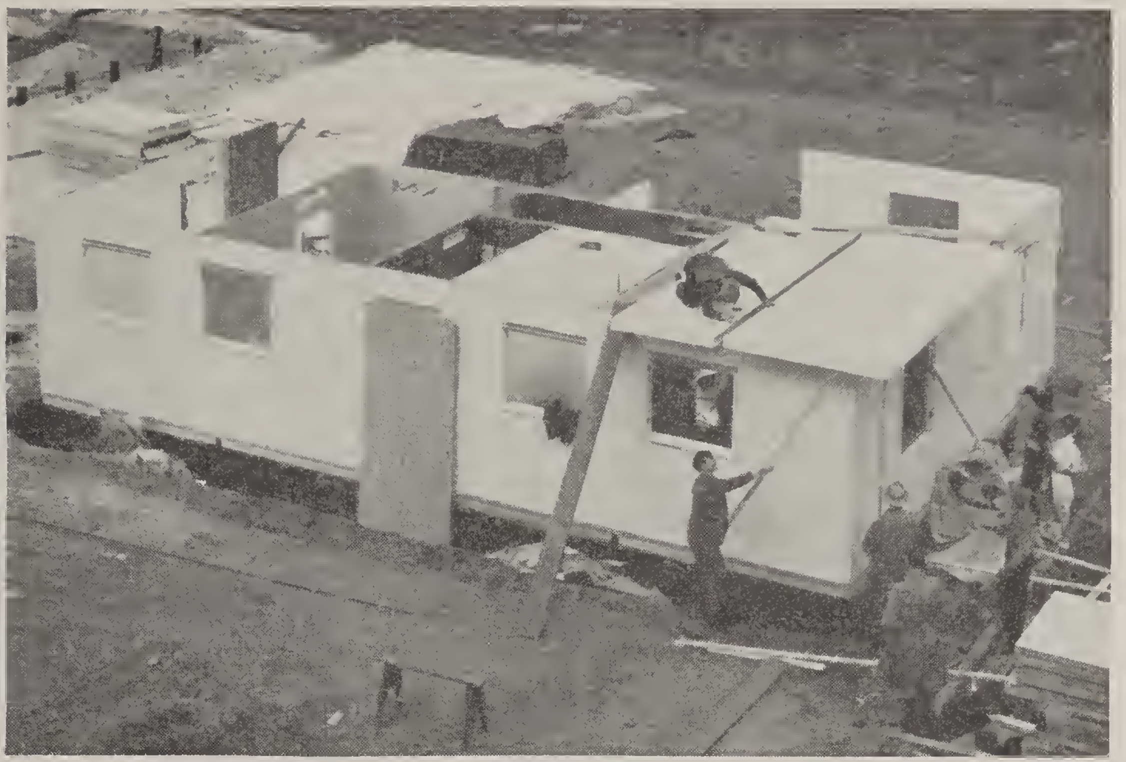


Erection of demonstration prefabricated house at Forest Products Laboratory. M32421F

Plywood consists of three or more sheets of veneer glued together, with the grain of successive sheets laid crosswise each to each. The resulting material has distinct advantages for many uses. The natural tendency of wood to swell or shrink transversely with changing moisture conditions is restrained by the crossing of the grain. To reduce warping to a minimum, an odd number of plies is almost always used. The greater the number of plies, the more nearly is the strength of the piece equalized in the lengthwise and crosswise directions. Plywood offers greater resistance than solid wood of the same thickness to shearing, splitting, puncture, and the tearing out of fastenings near its edges. The fact that plywood can be made up in sheets much larger than boards sawed from the log makes for its rapid and efficient use in construction and fabrication. Necessarily, however, since the strength of wood across the grain is much less than along the grain, the gain in strength of plywood in the one direction is offset by a decrease in strength in the other below that of solid wood. This fact gives the preference to solid wood in uses in which longitudinal strength and stiffness of the material are of controlling importance.

Although plywood had its chief origin and a long and consistent development in the craft of furniture building, the thin and resilient layered material produced in quantity today is a creation of the machine age. The modern plywood industry was made possible by improved and cheap methods of veneer manufacture. Sawing was the first process to be used on an industrial scale. Although it produces excellent veneers, it wastes at least half of the log as sawdust. In the 1860's a machine for slicing veneers was developed, and it was followed a few years later by the first rotary cutter. Slicing and rotary cutting create no waste in dividing the wood structure, but they leave a part of the log uncut as a slab or a core. This, however, is often usable for other purposes.

While the slicing process holds an important place in the cutting of veneers from highly figured woods for fine furniture, rotary-cut veneer is the raw material for the major proportion of the world's present plywood production. It is made by rotating a log against a long, heavy blade, with a result similar to the unwinding of a roll of paper. Often the logs are softened before hand, by steaming or boiling, so that they will cut easily to produce smooth veneer.

The early plywood industry in the United States specialized on the production of chair seats and backs. With the gradual improvement of gluing materials and methods, the material found a quantity market in many other important products, both plain and finished. A very large use arose in furniture, especially paneled pieces in which the outer surfaces were of expensive and beautiful woods. The splendid adaptability of plywood to curved construction in furniture has been a demonstrated fact since the time of Louis XV. In the United States, the product has answered a like demand, permitting the evolution of new styles with rounded designs and the elimination of troublesome corners. Plywood has been widely adopted for interior wall panelings and for doors and partitions, where the beauty of wood grain in large surfaces of fine finish can be effectively displayed. One of the larger recent uses of plywood is in the interior construction of ocean liners. In the steamships *Europa* and *Bremen* the handsome effects of figures and matched plywood are exploited in great variety. In the *Queen Mary* more than a million square feet of plywood surface are featured, embodying at least 56 species of wood.

Plywood is now used in houses for ceilings, flooring, subflooring, sheathing, and wall facing. It furnishes floor boards and other parts for automobile bodies and structural and decorative interiors for modern steel railway passenger cars. It is in common use for the closed bodies of motor trailers. Impressive architec-

tural effects in buildings and bridges are made possible by the use of plywood in concrete forms, which produce broad plane surfaces of plasterlike smoothness. Large, thick plywood gusset plates have recently been made and shipped in carload lots for use in joining the timber framing of bridges.

Because common glues are more or less subject to loosening action by water, the use of plywood in surfaces exposed to weather was generally impractical until the advent of synthetic resin adhesives. By means of the hot press these have now been adapted to use as a water-resistant glue for wood layers, and cold-press resin adhesives are a prospect of the immediate future. Plywood thus enters still wider fields of service.

At the Forest Products Laboratory a utility building 160 feet long, 46 feet wide, and 19 feet high at the center was erected in 1934, with walls and roof sheathing of plywood, the exterior wall panels being made with synthetic resin adhesive. Resin-bonded plywood has been further developed and made available since that time and is appearing with increasing frequency in house exteriors. A system of dwelling-house prefabrication employing plywood unit panels is under development at the Laboratory, and at least one commercial concern is marketing houses of a similar type.

The newer ideas relating to plywood as a structural material originated in research done during the World War in the construction of airplanes. To produce fuselages and other parts of maximum lightness and strength, engineers made use of the "stressed-covering principle," a scheme whereby the surfaces are not only held in place and reinforced by the framing but themselves contribute a very large proportion of strength and stiffness to the structure. This result was achieved by thoroughly gluing plywood coverings to the framework, thus producing units of such high resistance to mechanical stresses that it was possible to reduce weight to a minimum.

In the system of house prefabrication that is being developed at the Laboratory this principle is fully applied. Walls and partitions and even the floors and roof decking of a demonstration house have been built of framed unit sections with glued plywood coverings, the space between facings being filled with insulating material. The sections are fitted with electrical connections, ready for assembly at the building site. Interchangeable sections permit wide variation in the size and architectural design of the house.

It is, of course, impossible to predict future trends in residence construction, but the results of industrialization in general warrant the belief that wood will find a wider field of service to the home builder through proper application of prefabrication principles. Research activities are proceeding with that end definitely in view, giving due attention to plywood along with other economical forms of wood construction.

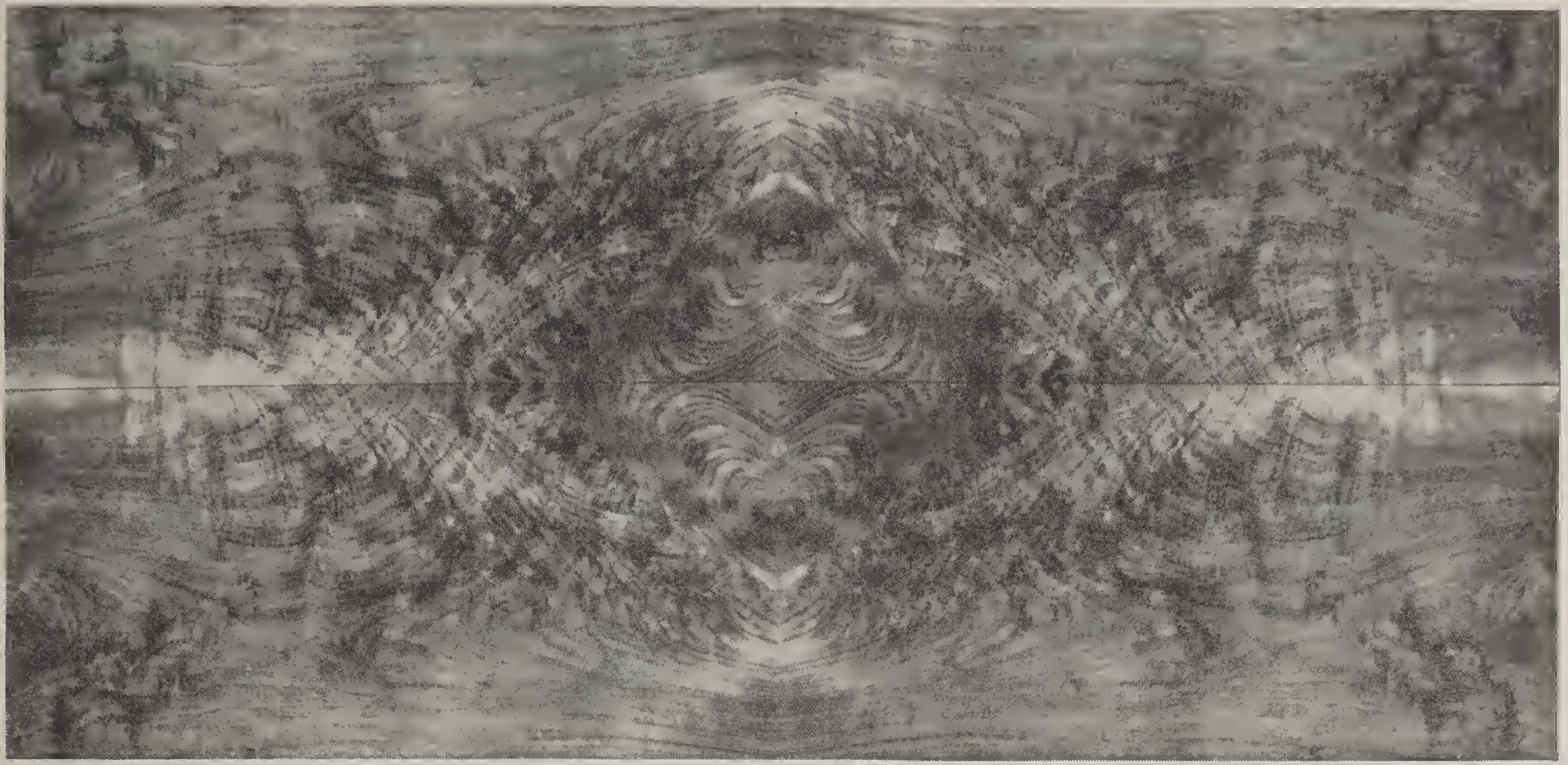
Prefabricated floor panel of plywood.

M24985F

Furniture.

Whatever the cultural development or mechanical skill of the period that produced it, the one thing common to the furniture of all the ages is that it has nearly all been made of wood. Strong, light, warm to the touch, easy to fabricate, attractive under careful smoothing and finishing, responsive to the will of artist and craftsman, wood stands without a successful rival in providing the movable equipment of the home.

Here the art of veneering has made its largest contribution to the satisfaction of mankind. The prime motive for the use of surface veneers is, as it has always been, to obtain beauties of grain and figure that are unobtainable, both physically and economically, with solid wood. Inexpensive straight-grained boards may form the base and carry the load, but in the surface quality of furniture we require



By careful matching of veneers, striking figured effects are produced. M1815F

the extra value that lies in pleasing variety and a degree of rarity.

The wood demanded for such service may be of curly or twisted grain, with fibers arranged in sinuous or contorted courses instead of nature's soberer parallel designs. In some high valued species the choicest veneer wood occurs in the crotches where a limb branches from the trunk. Here remarkable confluent patterns are found, from which, by careful slicing and subsequent matching of veneers, are obtained symmetrical designs of surpassing beauty. Stumps and burls of certain species furnish strangely variegated patterns. Wood having such configurations is very valuable for use as surface veneer and is usually cut in thicknesses of one twenty-eighth to one thirty-second of an inch. Lumber cut from such wood could not possibly be strong enough for the structural parts of furniture. The veneer knife divides the wood structure at every conceivable angle, often cutting straight across the fiber. It is just this irregularity that produces the beautiful patterns we cherish, the delicate shifting of light and shade, the curious variations of color.

The masters of cabinet working have been masters of veneering. In 1762, Louis XV of France ordered Jean Oeben to make the finest desk possible to build. It was finished 9 years later by Henri Reisener, Oeben's apprentice, after the master's death. This consummation of the cabinetmaker's art is said to have cost the king a million francs. It is preserved in the palace of the Louvre. Known as the Bureau du Roi, its inherent and associated values are beyond price. The delicate tracery of its unrivalled marquetry is a revelation, while the business details of drawers and cylinder top are examples to the present-day craftsman. The entire

M32684F

Responsive to the will of artist and craftsman, wood supplies most of the world's furniture.

desk is veneered. Its lavish effects would have been impossible with any other type of construction.

The strength and stability of plywood are a worthy support for the beauty of a surface veneer. The two

Forming the rim for a grand piano. M32646F

logically go together in the flat, paneled, or curved enclosing parts of furniture—in dressers, chiffoniers, consoles, presses, radio cabinets, sideboards, and, to a less extent in tables and chairs. There is little doubt that the modern development of plywood and veneered construction has provided Americans with more furniture, more tastefully designed, and of better quality, than they could ever have obtained at equal cost from the use of solid wood alone. All these advantages are postulated, of course, on sound workmanship, good gluing, proper selection of woods, and proper construction of the plywood.

Solid wood has an essential place in furniture, especially in the weight-bearing members and parts subjected to wear. The service requirements of tables and chairs warrant its use in large proportion. The owner of furniture built of solid wood has the satisfaction of knowing that the material has the same character throughout that is represented at the surface. If carving is desired, solid or carefully laminated wood is the necessary medium.

On the other hand, the cost of solid wood furniture may be high. It is far more subject to damage from shrinkage and swelling than properly made veneered furniture. The use of solid wood in wide panel surfaces today is not required for either efficiency, appearance, or long life. Its value and dignity, however, are beyond question, and the preference for it rests more largely on individual taste and means than on technical or aesthetic argument.

Even solid wood construction gives ample scope for good gluing practice. In particular, experience has taught the excellent qualities of large pieces or surfaces built of narrow or thin boards glued parallel to each other. Many fine table tops are thus constructed and so joined that the glue lines are scarcely noticeable. Thus "solid wood" itself verges on the composite.

Bending of wood to form curved parts of furniture and other products is an age-old practice. It has been limited by unavoidable breakage of pieces that are thick in comparison to the radius of bend. This difficulty can be avoided by assembling with glue a number of layers, each of which is thin enough for the required curvature. Such layered or laminated construction differs from plywood in that the grain is in the same direction in all layers. The method is increasingly used. Chairs of graceful design and unusual resilience and comfort are recent developments of this principle.

At least two pieces of furniture in the home make use not only of the strength and beauty of wood but of its acoustic properties as well. These are the piano and the radio. Radio cabinets are often among our choicest pieces of furniture from the standpoint of beauty alone, but wood is the chosen material because of the pleasing quality given to tone reproduction by its use. The grand piano is an impressive example of types

Solid wood has its essential place in furniture. M33077F

of craftsmanship that have been perfected through several centuries of persevering work. The smoothly curved lines of its sturdy rim are obtained by bending to form and gluing together a number of laminations, sometimes as many as 16. Its broad, flat top is an object lesson in the careful use of plywood or crossbanded construction to secure maximum resistance to warping. The exterior of the instrument exhibits the beauty of choice wood enhanced by the utmost refinement of surface and finish. Inside the piano the all-important sounding board is made of wood selected for its even texture, uniform properties, and resonance. The entire "action," from key to hammer, is a combination of woods chosen for lightness or strength or hardness in due proportion, the whole forming the most expressive mechanism known to the human touch.

M32647F

The entire "action" of the piano is a combination of woods.

New Developments in Timbered Construction.

The size of solid timbers is limited by the dimensions of tree trunks. Through gluing, however, the practical equivalent of solid timber can now be obtained without regard to that limitation.

The original impetus to this development came in Europe, where the scarcity of large timbers suitable for heavy construction led to the expedient of building them up in laminated fashion from lumber. The method consists in placing boards or strips edge to edge to the necessary width and gluing them flatwise to the thickness desired for the built-up member. Members longer than available lengths of lumber may be provided by joining boards end to end with long tapered glued joints. Care is taken to offset the edge-to-edge and end-to-end joints in successive courses, as in bricklaying, although in the case of edge-to-edge joints this precaution may be dispensed with if the boards are carefully fitted and glued before assembly of the member. Boards can be seasoned much more rapidly and with much less checking or fissuring than can large timbers; hence the gluing-up process offers a ready means of producing large "preseasoned" timbers of such character that disfiguring checks will be avoided, as well as warping and twisting of the members subsequent to their placement in a structure.

From the building up of straight timbers to the construction of laminated wooden arches was a simple step. In this case the flexibility of single boards permits them to be bent successively and clamped to a form as a group or assembly. As the glue sets, the curvature becomes fixed and the boards are combined into a unit. Wooden arches have different shapes according to the loading provided for. Often the "shoulders" are built up to extra thickness by applying more layers. The arch is the most important architecturally of laminated wooden members. Its strength allows its use without any trussing or bracing, so that it provides high, wide, unobstructed interiors. No matter how utilitarian the building, the use of these arches gives to its interior dignity and impressiveness. In several northern and central European countries they have been widely used for more than a quarter century in auditoriums, skating rinks, gymnasiums, riding halls, churches, railway stations, industrial buildings, exhibit halls, and other structures requiring large clear floor spaces. They have been especially favored in railroad structures and in buildings housing chemical industries because of their immunity to the fumes prevalent in such places. In this country their use began much later but shows promising development. They have been used in nearly a hundred structures, beginning with the Forest Products Laboratory service building erected in 1934, and including churches, auditoriums, gymnasiums, pavilions, garages, and barns.

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A high-school gymnasium framed with glued laminated wood arches.

Heavy wood members have demonstrated the important property of retaining their strength for a considerable period in a fire. Relatively slow burning, they may be badly charred but still retain sufficient strength to prevent early collapse of the building. Laminated beams and arches may be expected to be similarly effective.

Hitherto laminated structural members have been made almost exclusively with casein glue. The advantages of laminated construction of large members appear to be capable of further improvement by the use of the resin glues previously referred to. These glues, when heated, undergo certain chemical changes that make them insoluble in water and produce a strong bond between the glued surfaces. The difficulty in using them with wood of greater thickness than veneer has been in getting proper temperatures at the joint without causing shrinkage and checking of the wood. The development of resin glues that set cold or of new methods by which the required temperatures and relative humidities may be obtained in kilns offer attractive prospects for the formation of bonds in heavy members. Another possibility yet to be developed is the building of laminated members out of material chemically treated for resistance to decay fire, or insect attack—or the application of such treatment after the members are made.

The development of laminated construction is of great significance in relation to the country's future forest resources. It means that as large trees of virgin growth become scarcer, structural timber of adequate size and strength can still be produced from material which the second-growth forest will supply.

In the more usual types of trussed and braced construction, wood has had a long and important history. With the increasing precision and efficiency of modern engineering design, however, its use suffered a progressive handicap because of the inefficiency of prevailing methods of joining large timbers. Recent research has developed new metal fastenings, known as modern connectors, which greatly increase the efficiency of joints by affording better distribution of stress than is possible with the older types of fastenings such as nails and bolts.

More than 60 types of modern connectors are now available. They fall into three main classes, namely, plates provided with teeth, spikes, or corrugations; rings, plain or toothed; and disks or wide, short dowels,

usually tapered each way from the middle. Their diameters range from 2 to about 10 inches. They are placed between the faces of two pieces to be joined and are embedded half in each piece. Precut grooves or holes receive the plain rings or disks. Toothed connectors are often forced into position by pressure. A bolt through the center of the connector holds the assembly in position. One well-known type of connector joins the members by means of metal straps or plates anchored to the wood by inset rings.

Through the better efficiency of modern connectors new fields are opened to timber construction. The system lends itself especially to shop fabrication of material for assembly at the site. More than 3 million of the connectors have been sold thus far in the United States. They have been used in timber trusses with spans exceeding 100 feet and in trussed arches spanning more than 200 feet. By their use lofty radio towers are built of wood; one, in Europe, is more than 600 feet high. The nonmagnetic character of wood gives to such towers an increased broadcasting range of 30 to 50 percent.

New gracefulness arising from engineering efficiency is seen in timber arch bridges built with modern connectors. An impressive example, enhanced by its natural surroundings, is a highway arch span of 135 feet in the Umpqua National Forest in Oregon. This bridge, built of timber preserved from decay by creosote, is 45 miles from the nearest railway. Economy was necessary in its erection. The simple procedures

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Types of modern timber connectors.

Below: Mole's-eye view of radio station WRVA tower, Richmond, Va., built of timber with modern connectors.

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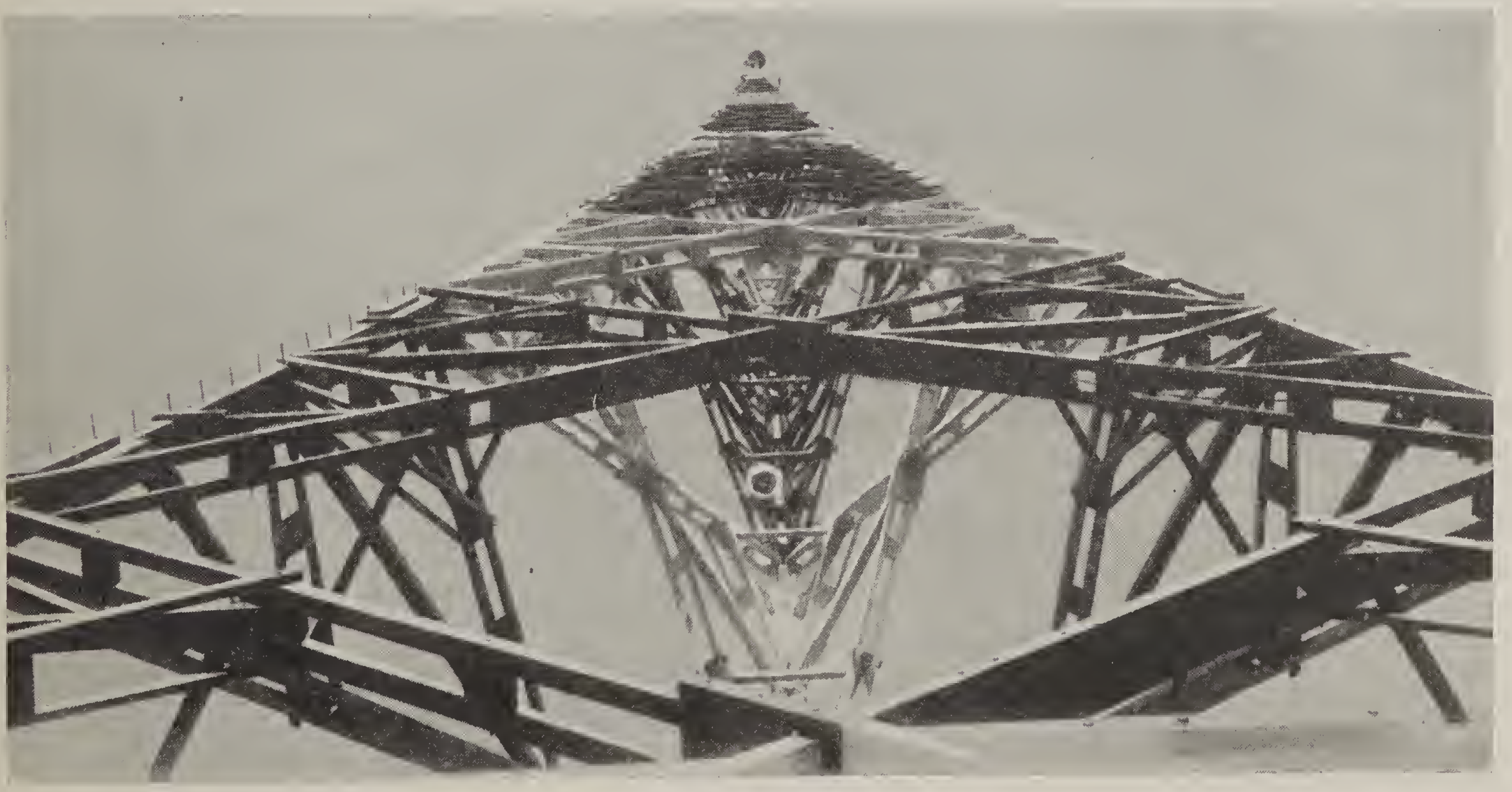
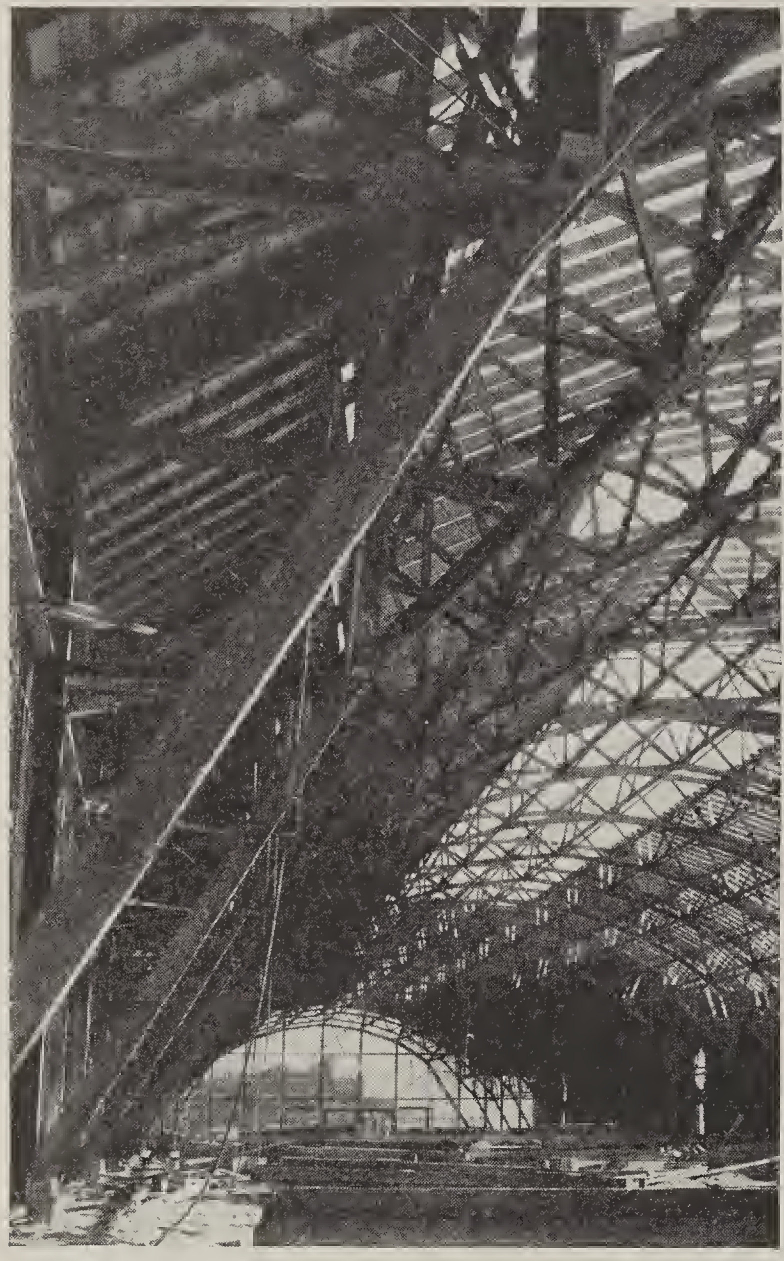


required in assembly made possible a thoroughly satisfactory job by Civilian Conservation Corps labor.

The durability of wood when properly installed and safeguarded is shown by such examples as Timothy Palmer's three-span covered bridge across the Delaware River at Easton, Pa., which was used from 1805 to 1895. A wooden bridge across the Cheat River at Rowlesburg, W. Va., was built in 1834 and was in use until about 1930. It is still standing (1938) in good condition. Authorities state that there are still in service in the United States several hundred wooden bridges that are from 90 to 100 years old. Many others have been removed while still in sound condition because of the growth of wheeled traffic far beyond the weights the bridges were intended to carry. Europe affords many examples of wooden bridges that are still in use after several centuries of service. With modern methods of preservation and construction, wooden bridges can be assured a service life extending far into the future, at moderate cost of construction and upkeep. Their reconstruction will in many cases be dictated by changing traffic requirements, in which case the possibilities of satisfactory remodeling and reuse of material will be of additional advantage. Strong wooden bridges made durable and economical through preservative treatment of timber and the use of modern connectors afford a possible solution of problems that are causing more and more concern to highway authorities.



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Two hundred-foot trussed timber arches in building for 1939 Golden Gate International Exposition, San Francisco.

Railway Uses.

In the maintenance of track, the construction of small stations, sheds, and tool houses, the building of bridges, the erection of snow sheds and fences, and the carrying of telegraph and telephone lines, wood is called into service in enormous quantities by railway companies. The bulk of the traffic is carried by freight cars, whose construction requires a large volume of wood. In no field, perhaps, has competition between materials been more active than in railway uses. Modern industry provides a wide choice of materials from which engineers and executives choose that which best meets the requirement from all points of approach—first cost, depreciation, repair cost, and satisfactory service. In this contest wood has stoutly stood its ground.

Even the modern all-metal passenger train must depend upon wood in order to function, for no widely acceptable substitute for the wooden cross tie or sleeper has yet been found. In the last 50 years more than 2,500 patents have been granted for ties of other materials, but, in general, railway traffic continues to move on a wood foundation. Today more than a billion wooden cross ties are in use in the United States—enough, if placed end to end, to encircle the earth 70 times.

There was a time when the prodigious consumption of cross ties made it seem as though some other material would have to replace wood; but the increasing use of preservatively treated ties has lengthened service life and substantially reduced the annual requirement. In 1910 nearly 150 million ties were purchased, of which only about one-fifth were treated. In recent years 50 million, or less, have been purchased annually, of which more than three-fourths are treated. Several important roads report rates of tie renewal between 50 and 75 per mile per year. About 100 per mile per year would be nearer the present average for the 420,000 miles of main-line and yard trackage throughout the country.

Ties are cut from a number of species of wood. Many are hewn from the logs by hand. The prefer-

ence, however, is for the sawed tie because of its greater uniformity, its lower average cost for treatment, and its better handling qualities.

The reasons why wood cross ties have held their position in competition with other materials and a flood of inventions are quite definite. The American railway track is a flexible, yielding mechanism, constructed so as to give to the terrific impacts of rushing masses of iron, yet elastic enough to retain its form and strong enough to bear the mountainous loads placed upon it. It is compounded of ballast, ties, tie plates, spikes, and rails in such a manner as to be a dynamic rather than a static part of train movement.

In this complex assembly the wooden tie plays a fundamental role because of its cheapness, strength, elasticity, resistance to shock, and relative ease of replacement, not to speak of its electrical insulating properties, which are essential to the operation of an increasing mileage of automatic signal systems. Ties sometimes last 30 to 40 years, and their average life is increasing as a result of both preservative treatment and better service conditions. The wide rail bases of today, the increasing use of tie plates, close and regular spacing of ties, and solider end connections of rails are saving ties a good deal of the terrific cutting and punishment they formerly endured. Whatever the improvement, it is all in favor of the wooden tie, which has weathered hard service and now seems established for a long time to come.

In the construction of freight cars, wood has been almost completely displaced from the frames but retains a firm position in the bodies. In 1929, about 10 times as many boxcars with steel frames and wood or part-wood bodies were built as were constructed of all steel. Flatcars are preponderantly built with steel frames and wooden bodies and floors. The same is true of refrigerator cars and stock cars. Gondola and hopper cars are being built more and more of metal, although for the hauling of slags and high-sulphur coals wood bodies are required to withstand corrosive effects. The 1927 and 1929 census reports indicate that approximately one-third of the gondolas built had wood bodies. Tank cars are all metal except those for corrosive liquids. There is a marked tendency in boxcar construction to line metal cars with wood. In passenger cars the present practice is all-metal construction, except that to a limited extent wood is used as a decorative interior. For that purpose plywood is assuming increased importance.

Wooden sides and tops for freight cars have certain very definite advantages. Repair costs, which bulk large in railroad finances, are low with wood. Damages to shipments susceptible to injury by condensation water do not occur in wood-bodied or wood-lined boxcars. Light weight, too, is an important consideration. In refrigerator cars, the insulating value and resistance to corrosion of wood give it the preference over metal.

M32652F

More than a billion wooden cross ties are in service on American railway lines.

All boxcars require wood runways along the top for safe footing. Car floors of wood afford superior satisfaction in use. They have definite shock-absorbent value and provide a convenient surface for nailing the blocking that is often required to prevent shifting of freight. Considering the extra hard service conditions, wood floors wear long and well.

In 1929 the railroads used over 157 million dollars worth of wood. In 1928 more than 1 billion board feet of lumber was used in the construction of cars alone. It is not an exaggeration to say that the historical development of American railways into the gigantic and ramified system that we know today and likewise their economical operation and maintenance would have been impossible without the vast supply of wood coming from our forests.

Furthermore, railroads derive an enormous revenue from the transportation of forest products. In 1935 the freight loading of primary products such as lumber, pulpwood, posts, and piling amounted to 42½ million

tons. In years of greater market activity more than 100 million tons have been carried. When the tonnage of paper and its products, manufactured wood products, and packing and crating materials are added, the yearly amount is largely increased. In all, about 10 percent of all tonnage hauled by the railroads comes from the forests.

Poles, Posts, Piling, and Mine Timbers.

Ninety million miles of telegraph and telephone wire, nearly half of it carried above the ground on wooden poles, forms a veritable web of communication over the country. The actual mileage of pole lines is not definitely known, since a pole may support one or many wires. The total, however, is great. Telegraph companies own more than 256,000 miles of pole lines and telephone companies far more. A very large number of poles carry electric utility wires also. Available statistics indicate an annual sale of nearly 3½ million poles. The business of pole-line extension and maintenance is very large and is destined to increase with the more thorough electrification of rural districts.

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Poles air-seasoning in a Texas yard prior to creosoting.

The strength and elasticity of wood and its good insulating properties make it an ideal material for the heavy job of carrying aerial wires. It can stand up under the load, take the stresses of winds and storms, and give many years of service. Electrolysis and corrosion never affect its underground base. In earlier days untreated poles were largely used, but decay, especially at the ground line, was heavy. At present many poles have their butts impregnated with preservative, and many more are impregnated full length for protection against decay and other destructive agencies above ground. The result is that the average life of poles is increasing. It is evident that until the distant day when all wires will be underground in a densely populated nation, wooden poles will continue to carry the wires upon which are transmitted our messages and much of our electrical power.

The service of piling to civilization may be justly described as basic. Many of our towering steel and stone skyscrapers rest on wooden piles driven to bedrock. Piles for supporting piers and wharves, for breakwaters, for dams and bridges, jetties, and channel controls were used from 1925 to 1929 to the extent of more than 1,363,000 pieces annually. Tough, and possessed of high crushing strength along the grain, wood piles can withstand the heavy blows of the pile driver and, when in place, support enormous loads. Where exposed to decay or to marine borers they are impregnated with perservatives. Where driven below the permanent water table in wet earth they are sealed by nature against damage and will outlast the structures they support.

Transportation and communication systems and the whole economic structure of commerce would collapse but for the products of the mines. The mines, in turn, could hardly operate without the framework of timber that holds back their walls and roofs and supports their track systems. The lives of 750,000 miners are protected always by strong supports of wood, which are used at a rate of about 185 million cubic feet per year.

It is hard to imagine a service performed under more exacting conditions. Exposed to all degrees of damp-

Mine timbers perform indispensable service under the hardest of conditions.

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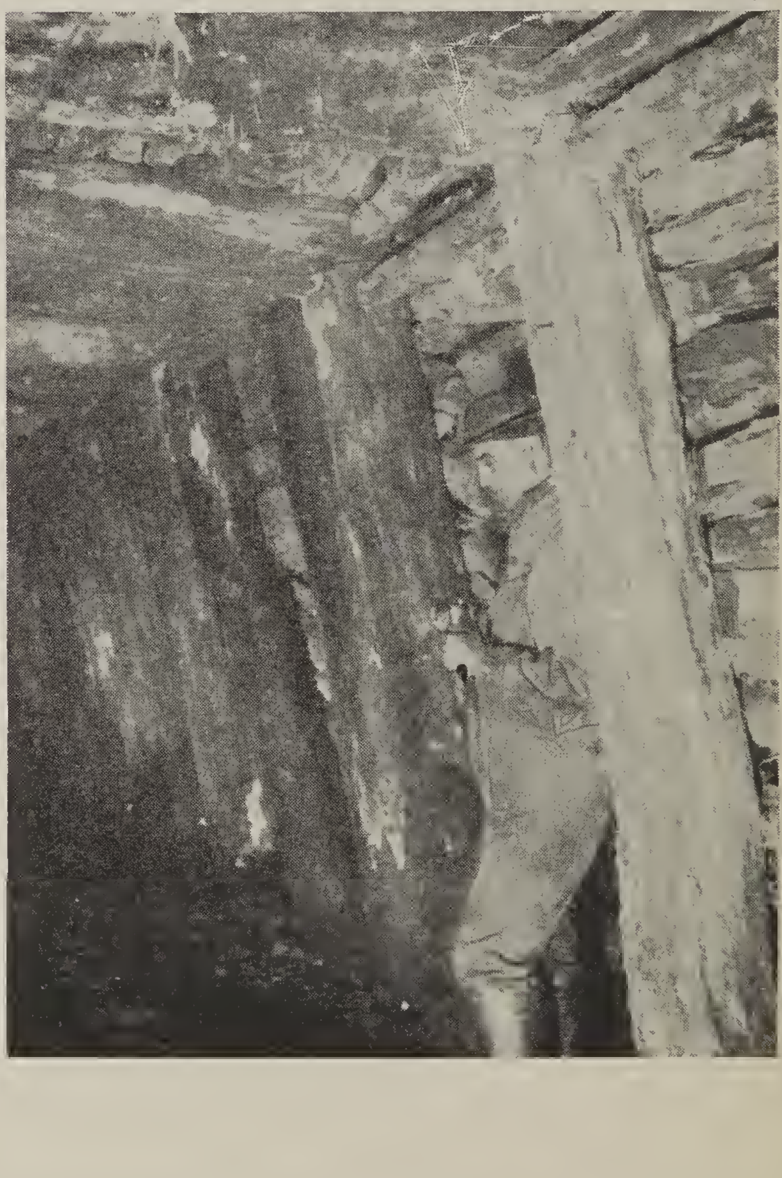

ness, under continual strain, and subject to corrosive seepage, no other material costing so little could well be conceived to replace wood. Some mine timbers are now treated with preservatives, especially those for supporting galleries expected to be in use many years, and the practice is extending. In short-lived workings cheaper untreated timbers can give the desired length of service before decay destroys their safe bearing power.

By far the largest use for wood in contact with the ground is as fence posts, which furnish enclosure for land as far as man's claims extend. Cheap and effective preservative treatments now make it possible for the farmer to use species of wood for posts that were formerly regarded as worthless, obtaining from them a service life surpassing that of some very durable species.

The broad bearing surfaces of wooden posts against the earth in which they are set and the strength of the post itself are inherent advantages in fence building. The ease with which nails and staples can be driven make fence erection a simple process adapted to ordinary tools and skill. The general suitability of wooden fence posts is amply attested by their use wherever available. The annual requirement of the United States for use in new fences and replacements is estimated at from 400 to 600 million posts, or 3 to nearly 5 fence posts per capita of population. This enormous consumption will, however, undoubtedly decrease as old posts are replaced with new ones treated with preservatives.

Research points the way to greater heat value from wood in stoves and furnaces.

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Experimental preservative treatments of wood at the Forest Products Laboratory are checked by subsequent service tests.

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Wood as Fuel.

The farmer uses wood in construction, in building fences, and in other ways, but largest of all is his consumption of wood for fuel. Recent estimates place the total quantity of wood used as fuel in country, town, and city at the huge figure of more than 61 million cords per year, representing the largest single form of consumption of tree volume in the United States, with the possible exception of lumbering.

As fuel, wood supplies a diversity of needs, as in house heating, the firing of sawmill boilers, cooking, some commercial baking, and the curing of tobacco and meat products. In some of its uses it may never be displaced, but in others large displacements have occurred and are still in progress. On the other hand, the development of more efficient wood-burning equipment for cooking, heating, and industrial service prom-

ises to give wood and wood waste a stronger economic hold as fuel where an adequate supply is available.

The future may see a large development of the use of wood as a source of fuel for internal-combustion engines. One method is to convert wood into the liquid fuel, alcohol, the production of which is noted in a later section. Another method, seen in operation on many trucks and busses in Europe, is to convert wood (or charcoal) into a gas in a special generating unit, from which the gas is fed directly to the engine. Wood and other plant materials as a source of motor fuel offer attractive possibilities in countries lacking adequate petroleum supplies. In the United States, relatively cheap and abundant gasoline removes this use of wood from practical consideration at present; in the future, however, it may prove of vital importance.

The following discussion, taken from Senate Document No. 12, Seventy-third Congress (1933), A National Plan for American Forestry, broadly outlines the trends in wood-fuel uses:

The decline in fuel wood consumption is largely a matter of changes in requirements and competition of other materials, paralleling somewhat the changes in lumber requirements. Perhaps the first great change in domestic fuel requirements came with the introduction of the base-burner and coal. Without attempting to list all changes chronologically, there may be mentioned gasoline and gas stoves for cooking, the furnace or central heating plant using coal, oil, and gas, and electricity with electric appliances. That these changes are still under way is shown in the recent advances in distribution of gas made possible by welded pipe. There were over 40 thousand miles of natural-gas trunk lines in 1929.

Considering wood as chiefly a domestic fuel, the extent of competition of other fuels is illustrated by an increase in domestic consumers of natural gas from roughly a million in 1909 to 5 million in 1929. Domestic consumption of bituminous coal increased from 46 million tons in 1909 to 82 million tons in 1927, the latest year for which this figure is available. The domestic consumption of anthracite coal was approximately 48 million tons in 1927.

It is impossible to arrive at actual displacement of wood by other fuels from information available, but the above figures are at least suggestive. At 7½ tons per dwelling, the domestic coal consumption of 130 million tons in 1927 would supply fuel for over 17 million dwellings, or roughly the equivalent of all urban dwellings. This coal consumption was supplemented by artificial and natural gas, fuel oil, and other minor fuels. The typical domestic consumer consumes more than one fuel; that is, there is an overlapping in number of consumers of coal, oil, gas, electricity, and wood. Furthermore, coal, oil, and gas compete with one another just as they compete with wood.

The decline in fuel wood requirements has been very largely in the urban field. And since consumption of wood for fuel is now largely confined to rural sections where its use will most likely be maintained, requirements may be approaching a minimum at current figures. The general opinion is that consumption of fuel wood has actually increased since 1929, due to present economic conditions. This may be only temporary, but it is unmistakable evidence of advantages in having a supply of fuel wood available.

Products of Wood Conversion

USEFUL as wood is in the form in which nature provides it, science has shown the way to transformations that add greatly to its importance as a resource of our developing civilization. Although wood conversion products as yet rate far below lumber and other primary products in bulk of wood consumed, major interest attaches to the selective needs that they satisfy, the high values added to raw material in their production, and their increasing potentialities as a basis of forest-land values, useful manufactures, and productive employment.

Pulp and Paper.

Cellulose is at present the most important part of wood from the chemical-industrial point of view. This remarkable material is nature's framework and construction material with which are formed the walls of cells that make up the bodies of all plant life. It is made in the laboratory of the plant by putting together in a specific way molecules of ordinary glucose, the kind of sugar that is the main substance of corn sirups. Glucose is originally formed in the leaves of the plant from carbon dioxide from the air and water from the soil, in cooperation with sunlight and the green pigment of the leaves, chlorophyll. Thus from water, air, and sunlight, nature produces a bountiful supply of raw material that the modern age finds increasingly necessary in its affairs. Cotton fiber is almost pure cellulose, used for textiles wherever the plant has been known. From the cellulose fiber of flax men for ages have obtained, with great trouble, a prized material for fine fabrics. Wood, however, is the most abundant and compact source of cellulose in the plant world. More than half its substance is cellulose fiber. But not until the nineteenth century was this wealth of fiber unlocked and made useful.

It made its appearance as paper, a product formerly made almost exclusively from cotton and linen rags. As printing demands increased, the supply of rags became more and more inadequate and the search for alternative materials more and more intense. The workmanship of the common wasp, which makes its nest of paper from finely chewed wood, long ago gave scientists an inkling of wood-fiber possibilities. Many experiments were tried, and at last, in 1840, a successful wood-pulp grinding machine was developed in Germany. Fourteen years later the grinding process began to be used in commercial pulp production, and in 1866 it was introduced in the United States. Today ground wood pulp, made principally from spruce and hemlock and other conifers having little resin, supplies more than three-fourths the material of all the cheaper printing papers and nearly one-half the material of the various paper boards.

Early efforts were made to obtain a purified form of cellulose fiber from wood by chemical means. Success in this direction was first attained in England, in 1852, through the development of the soda process, a method of alkaline cooking. In the United States it became well established by 1863. It is used at present mostly for the pulping of soft, short-fibered woods of broad-leaved species such as aspen and gum. The pulp has a large and important use in book and magazine papers, being valued for its whiteness, nontransparency, and good printing quality.

The acid or sulphite process, discovered by Benjamin C. Tilghmann, an American, in 1866, was first brought

Wood is the most abundant and compact source of cellulose in the plant world—the raw material for a gigantic development in this country of pulping and papermaking.

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Mechanical grinding of wood produces pulp containing both cellulose and lignin. Refined pulp is usually added to make paper of required strength and whiteness.

Chemical cooking of chips yields refined cellulose pulp.

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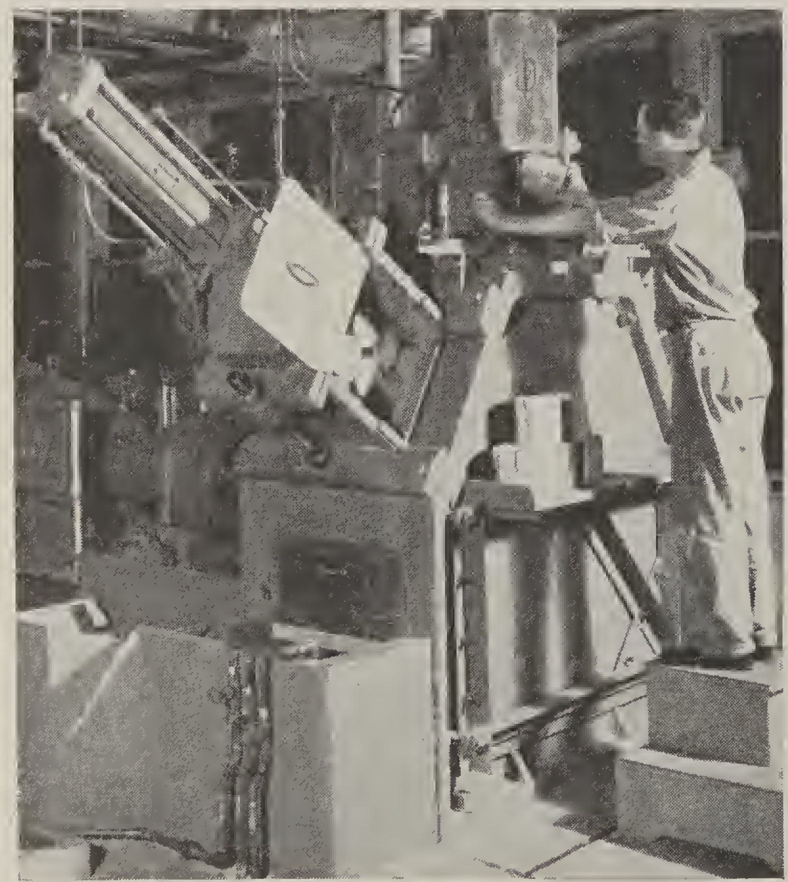

into practical operation in Sweden. It was introduced commercially in the United States in 1884. Applied to coniferous woods low in resin content, it now produces pulp in greater volume and for more varied uses than any other process. Sulphite pulp furnishes the United States with material for one-fourth of its newsprint and book papers, one-tenth of its boards, more than one-third of its wrapping paper, and a major part of its writing and other fine papers. The pulp is very strong and can be bleached to a high degree of whiteness. Besides its use in pure form for many papers, it is also the standard material for admixture with other pulps to improve the quality of the product in strength or color or both. Highly refined sulphite pulps are used in quantity for conversion into rayon.

The sulphate process, alkaline in character, originated in Germany about 1883. From the time of its introduction in America, shortly after 1900, its importance has constantly increased. It has proved most useful in reducing resinous woods, particularly the southern pines, to pulps suitable for strong wrapping paper and container boards. The pulp is commonly used without bleaching; the product is familiar everywhere as the tough brown paper called kraft. At present a phenomenal increase in sulphate-mill capacity is taking place in the South. Research at the Forest Products Laboratory and elsewhere has shown the way to modifications of the reduction process and bleaching methods, by which the pulp can be adapted to the production of many papers besides kraft; the findings are now being applied commercially, and as a result bleached sulphate pulp is entering a still wider field of usefulness.

From the time that wood became the common raw material of paper, in the late 1880's, the development of pulping and paper making in the United States has been nothing short of gigantic. Domestic manufacture of paper and paperboard in 1936, according to preliminary census figures, was nearly 12 million tons. The Nation's consumption, including imports, was no less than 14½ million tons, or 225 pounds of paper and boards for every man, woman, and child in the country. This vast quantity of cellulosic material was the product of approximately 15½ million cords of pulpwood. Trade statistics indicate that it was used in the following forms and relative amounts:

	Percent
Package boards and wall boards	36.3
Newsprint paper	25.4
Wrapping paper	12.4
Book paper	9.8
Writing paper	4.0
Tissues	3.8
Building papers	3.7
Absorbents, covers, and miscellaneous	4.6

The material classed as miscellaneous is used in so many diversified forms that no detailed accounting of it is attempted. More than 9,000 uses of paper have been enumerated. Many that are small in tonnage requirements nevertheless contribute important services in the organization of modern life. There follows a list of products of paper or pulp in which the substance may sometimes be concealed by the form:

M32654F

Modern paper-making machines of this type can turn out paper from 10 to 20 feet in width at a speed of 1,000 feet per minute.

SOME SPECIALIZED PRODUCTS OF WOOD PULP AND PAPER

Ammunition	Hats
Artificial flowers	Jars
Artificial leather	Lace
Artificial straws	Lamp shades
Baskets	Napkins
Blankets	Pails
Bottles and caps	Pencils
Boxes	Plates
Cartons	Ribbons
Combs	Rugs
Cups	Shoe counters and insoles
Doilies	Spools
Dolls	Suitcases
Dry mats for printing	Surgical dressings
Felts	Textiles
Forks and spoons	Twine
Game counters	

Although the United States far outdistances other nations in the use of pulp and paper products, it must be acknowledged that consumption is not paying its full returns in American forest economics. More than half of our paper supplies are not the product of American forests at all but are shipped in from abroad either as finished paper or as pulpwood or pulp for further conversion.

Two main reasons may be assigned for this situation. The first is that, despite recent developments in southern pine, the pulp and paper industry is still dependent on a very few species. The second, which is related to the first, is that the industry is, in the main, concentrated within easy transportation distance of eastern spruce and hemlock forests and the principal pulp and paper consuming markets. As native supplies of spruce and hemlock have been progressively depleted, the tendency of the industry has been to rely more and more on imports of these species from beyond the border rather than to migrate to distant regions of the United States and utilize new stands of similar or of different woods.

M26380F

Pulps are further refined in the beater.

In view of the foregoing, the task of research in furthering the production of pulp and paper from domestic material is clear. This is to increase the possibilities of economical production, higher yields, and better pulp quality from our native woods, both those now preferred for pulping and those not now used extensively or not used at all. A determined research attack on these problems is being made by governmental and other agencies. Its results already assure large developments in the pulping of abundant pines and

M32449F

Diversified paper products serve many needs

hardwoods and promise increasing social dividends in productive land use and in employment for American workmen.

Rayon and Related Products.

Synthetic fibers, which may be designated in general as rayon, are the outstanding contribution of the twentieth century to the world's textile requirements. They consist of cellulose chemically modified and spun into silklike filaments, strands, and yarns. These are woven into a great variety of fabrics, with which the public is now thoroughly familiar. The manufacture of synthetic fibers in the United States increased from less than a third of a million pounds in 1911 to about 300 million pounds in 1937. Their consumption first exceeded that of silk in 1926 and is now five times as great as that of silk, or about equal to the consumption of wool.

About four-fifths of all rayon is produced by the viscose process, in which the cellulose is treated with caustic soda and carbon bisulphide. Most of the remainder is produced by the cuprammonium process, using copper oxide and ammonia as conversion agents, and the acetate process, using acetic acid. In all three processes the original cellulose fibers are changed into a thick, sirupy solution that is pressed through a group of exceedingly fine openings to form long filaments. As these emerge and solidify, either in the air or immersed in a liquid, according to the process used, they are put under tension and formed into strands.

More than 60 percent of the rayon now produced is obtained from highly purified wood cellulose, mostly by the viscose process. Developments in progress indicate that other processes may utilize wood to an increasing extent in the near future. At present their main raw material is cotton linters, a coating of short fibers formerly left on the cottonseed but now recovered by special ginning and marketed for a number of uses.

The synthetic fibers take up dyes and hold them better than does the original cellulose. Their strength and wearing qualities, however, decrease in proportion as the molecular structure of the cellulose is degraded or broken down. The constant quest of the chemist is therefore for adaptations and modifications of processes that will yield continuous fibers with the least possible alteration of the cellulose molecule. The progress that is being made in this and other respects is proved by the marked superiority of present-day fibers over those offered to the consumer in earlier stages of the industry.

Viscose solution ready for spinning.

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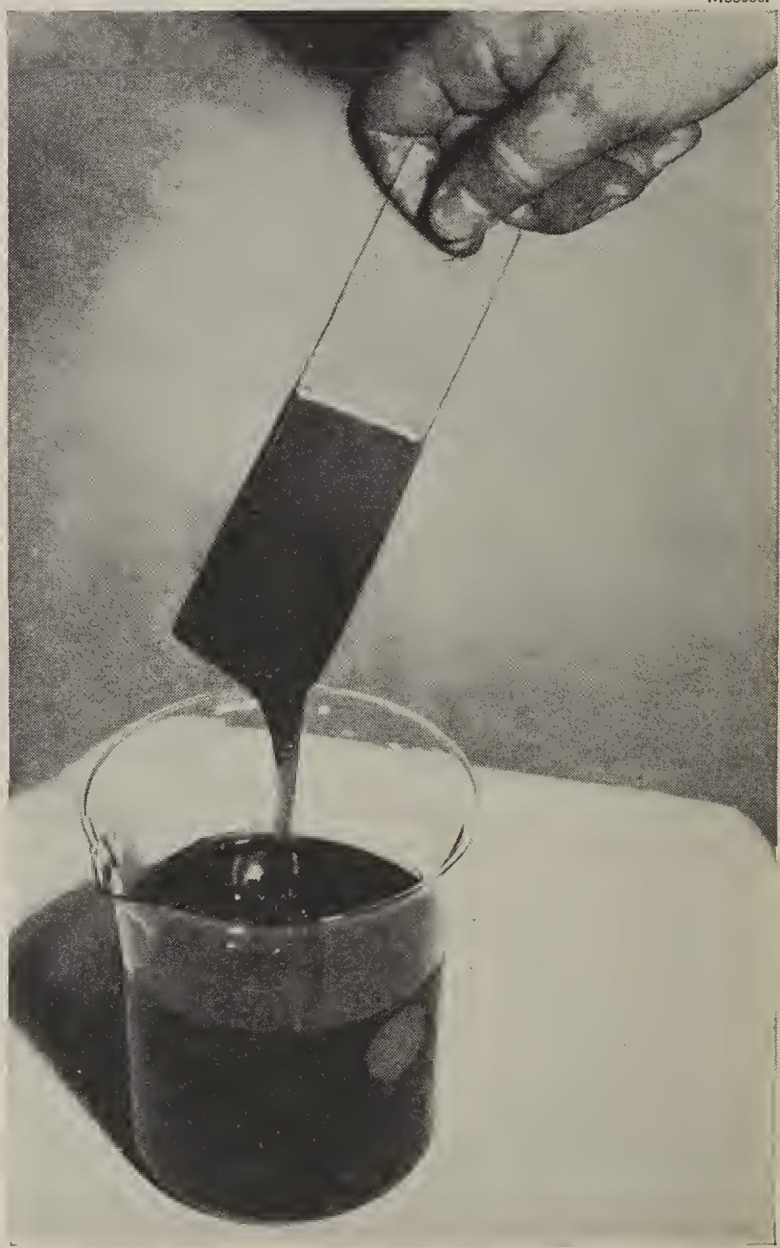

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A plant in Maine producing wood pulp for rayon manufacture.

By a modification of the viscose and acetate processes, the product may be precipitated in thin sheets as cellophane and similar transparent materials whose use is still on the increase for wrapping candies, dried fruits, cigarettes, stationery, dry goods, and many other

Spinning viscose solution into strands of rayon.

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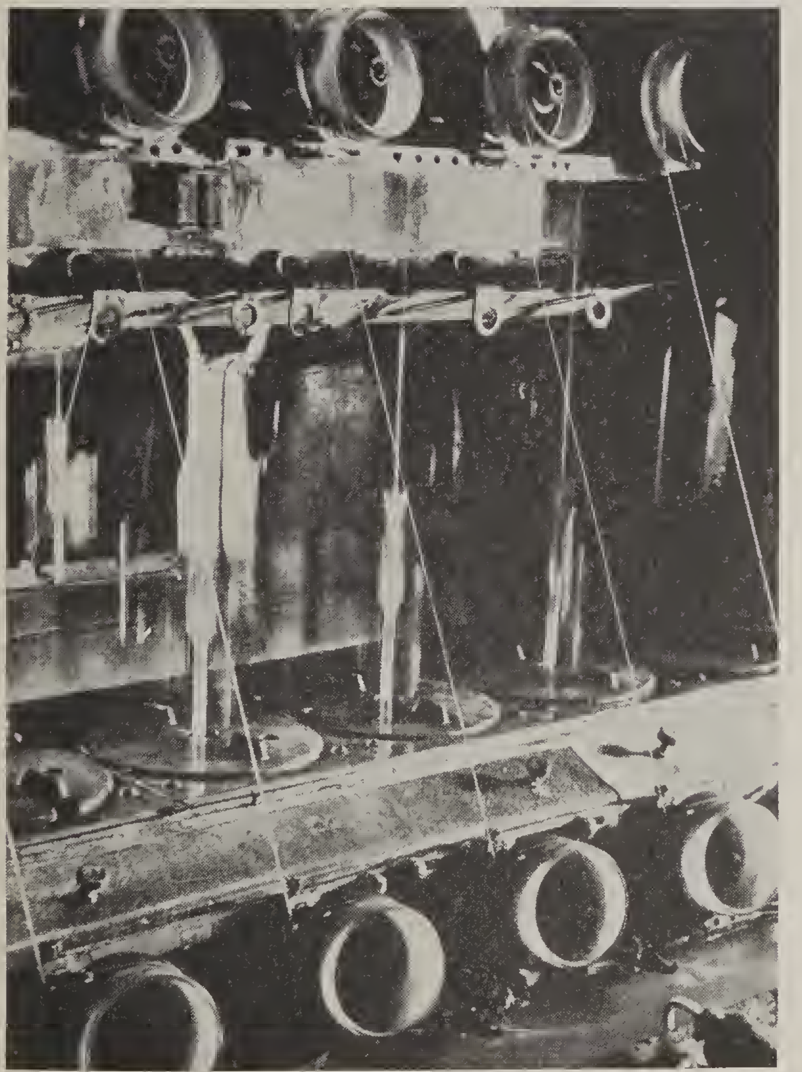

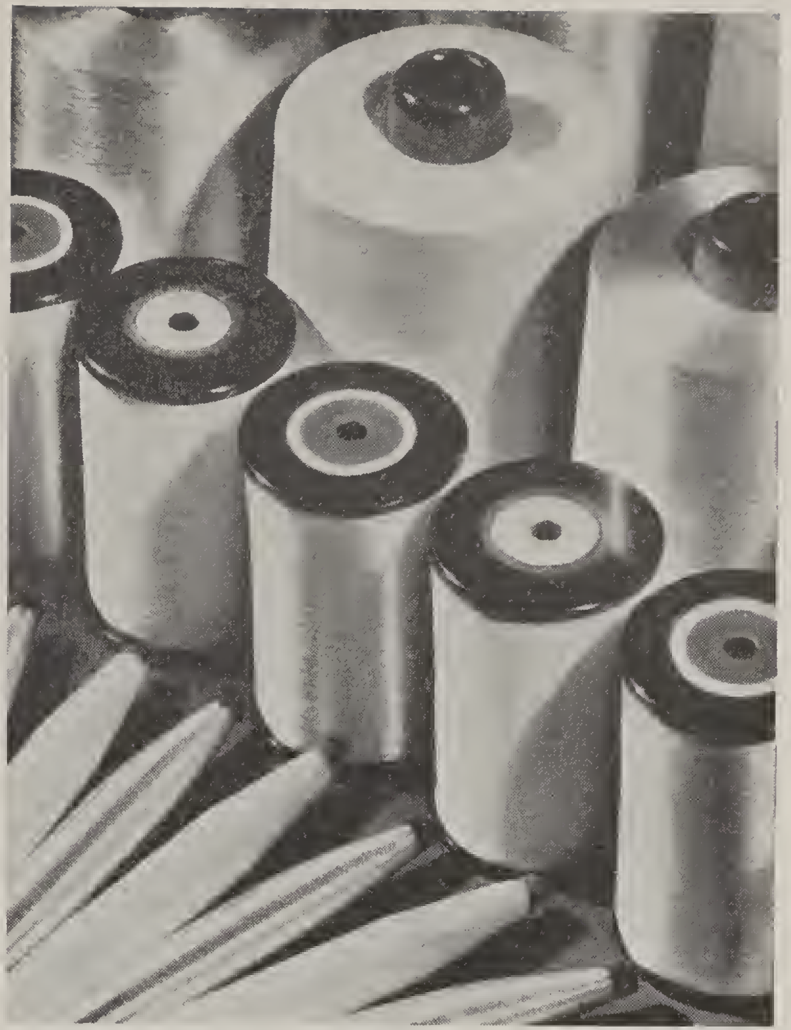

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Rayon yarns.

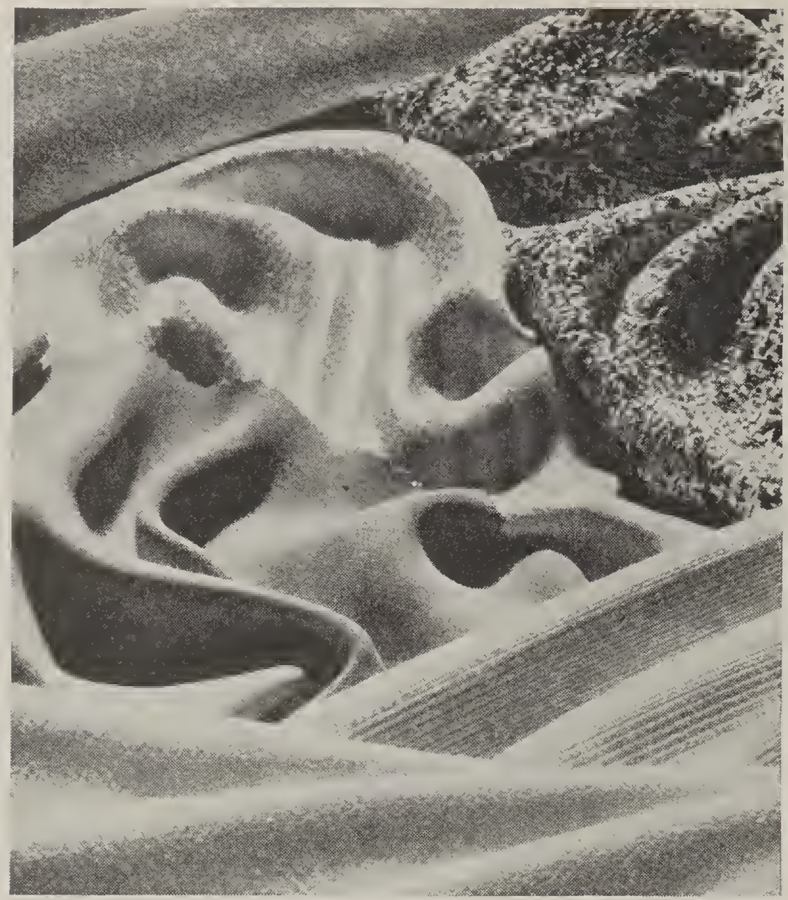
articles. Viscose even supplies casings for sausages, especially in the larger sizes.

Cellulose acetate, because of its low inflammability, is finding wide use for moving-picture film. Also, by reason of its plastic properties, it is formed into a great array of molded articles. The following list suggests the variety of its uses:

SOME PRODUCTS OF CELLULOSE ACETATE

Airplane dopes	Gold-leaf backing
Artificial hairs and bristles.	Imitation leather
Artificial sponges	Napkin rings
Bottle caps	Phonograph records
Brush backs	Shatterproof-glass cement
Buckles	Solid-alcohol filler
Cigar tips	Toilet articles
Fountain-pen barrels	

The action of nitric acid on cellulose produces cellulose nitrate, sometimes called nitrocellulose. One form of this material is a high explosive; others appear as collodion and photographic film. Many of the lacquers for automobiles and furniture have a cellulose nitrate base. When combined with natural or synthetic camphor, cellulose nitrate forms celluloid and similar products, appearing as plain and colored sheets and, again, as molded articles adapted to many uses.



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Rayon fabrics.

M33168F

Plastic products of cellulose acetate.

In recent years other products of the union of cellulose and various alcohols and acids have been commercially developed and are being used increasingly in plastics, lacquers, and the like. Evidently the prospect for new uses of purified wood cellulose is still

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Modern packaging materials from cellulose.

widening, and this remarkable product of the forests may be expected to play an even more important role in our material civilization in time to come.

Lignin Products.

In the chemical processes of pulping wood, the cellulose portion of the material is recovered and purified. More than half of the original wood is separated in solution and, for the most part, wasted. About half the waste consists of lignin, that is, a proportion representing 20 to 30 percent of the weight of the original wood. As noted at the outset, lignin may well be conceived as a cementing material that binds the cellulose fibers together in the wood structure. Chemical pulping, then, consists essentially of dissolving away the lignin and other materials and leaving the cellulose.

Despite the fact that this enigmatic substance, lignin, has been more or less closely studied for a hundred years, chemists admit that they do not yet know a great deal about its composition. They are not even in agreement as to whether it is a single substance or a mixture of several different substances. The obscurity of its chemical formula makes extremely difficult the utilization of lignin wastes, which in pulping liquors alone amount to millions of tons a year.

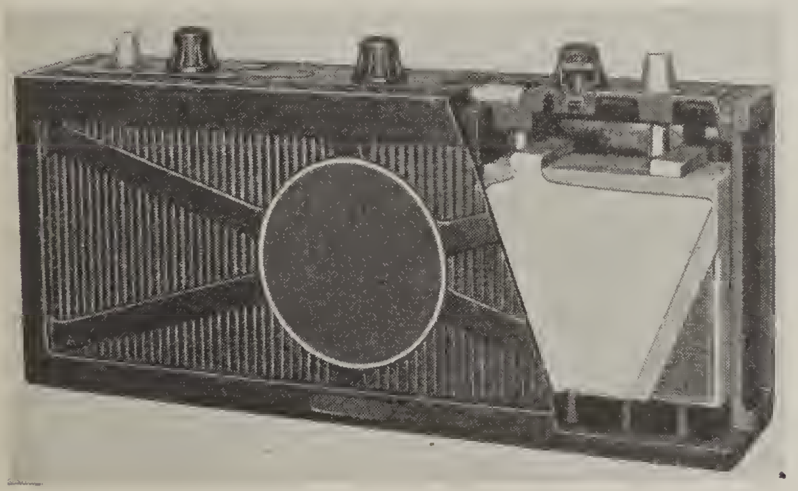
The search continues, however, and each year the work of dozens of laboratories adds a little to our knowledge of the nature of lignin. In the meantime, pending the ultimate solution of the problem, some promising uses for waste pulping liquor have been found. It has been used as binding material for road surfaces. Its value in this use arises from the somewhat hygroscopic character of lignin salts and their behavior in forming insoluble soil compounds. Pulping liquor boiled down to a semifluid mass is used as a paste in the laying

of millions of square yards of linoleum. In a recently patented electroplating process, addition of pulping liquor to the chemical bath is said to give tougher, more permanent metal platings. The chemical and mechanical properties of lignin itself have in recent years brought it into use as an expander for lead in the negative plates of storage batteries, by which means the life of batteries in automobile service has been increased severalfold. Excellent plastics have been made from sawdust, in which the lignin acts as the formative and binding agent. This field undoubtedly offers great promise for the utilization of waste wood. Lignin has been used to a limited extent in tanneries, and recently it has been used experimentally as the base for a fertilizer.

In the laboratory, oxalic acid, dyelike compounds, and other chemical derivatives have been prepared from lignin. Thus far, however, the larger economic usefulness of the lignin fraction of wood must be said to lie mostly in the future. Its waste on a large scale at present constitutes a loss to society, and its discharge into streams as spent pulping liquor is a positive detriment. Research has an important task to fulfill in determining its chemical structure and turning it to the service of mankind, as has been done, for example, in the case of coal tar, formerly a rank waste.

Wood-Flour Products.

Wood flour, as its name indicates, is wood ground to a fineness approaching that of wheat flour, the degree of fineness being varied according to the uses to which the material is to be put. In the United States from 25 to 40 thousand tons of wood flour a year is used. A light-colored product is generally demanded by the trade. Most of it is made from white pine sawdust and shavings, but a few other species enter into the total.



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Lignin used as an expander in negative plates of batteries has increased service life of automobile batteries severalfold.

About half of the wood flour used goes into linoleum. Ground cork is the preferred filler for the darker shades, but in inlaid linoleum, in which the pigmentation goes all the way through the material and patterns include light colors and delicate shades, the nearly white wood flour is used as filler.

One-fourth of the consumption of wood flour is accounted for in the manufacture of dynamite and similar explosives. In contrast, however, to the use of wood or cotton nitrocellulose itself as an explosive, the wood flour in dynamite serves merely as an absorbent for the powerful but delicate nitroglycerine. The sensitivity of nitroglycerine to shock is thereby so reduced that

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Patterned linoleums contain a considerable proportion of wood flour.

In plastic products molded from sawdust, lignin acts as the formative and binding agent.

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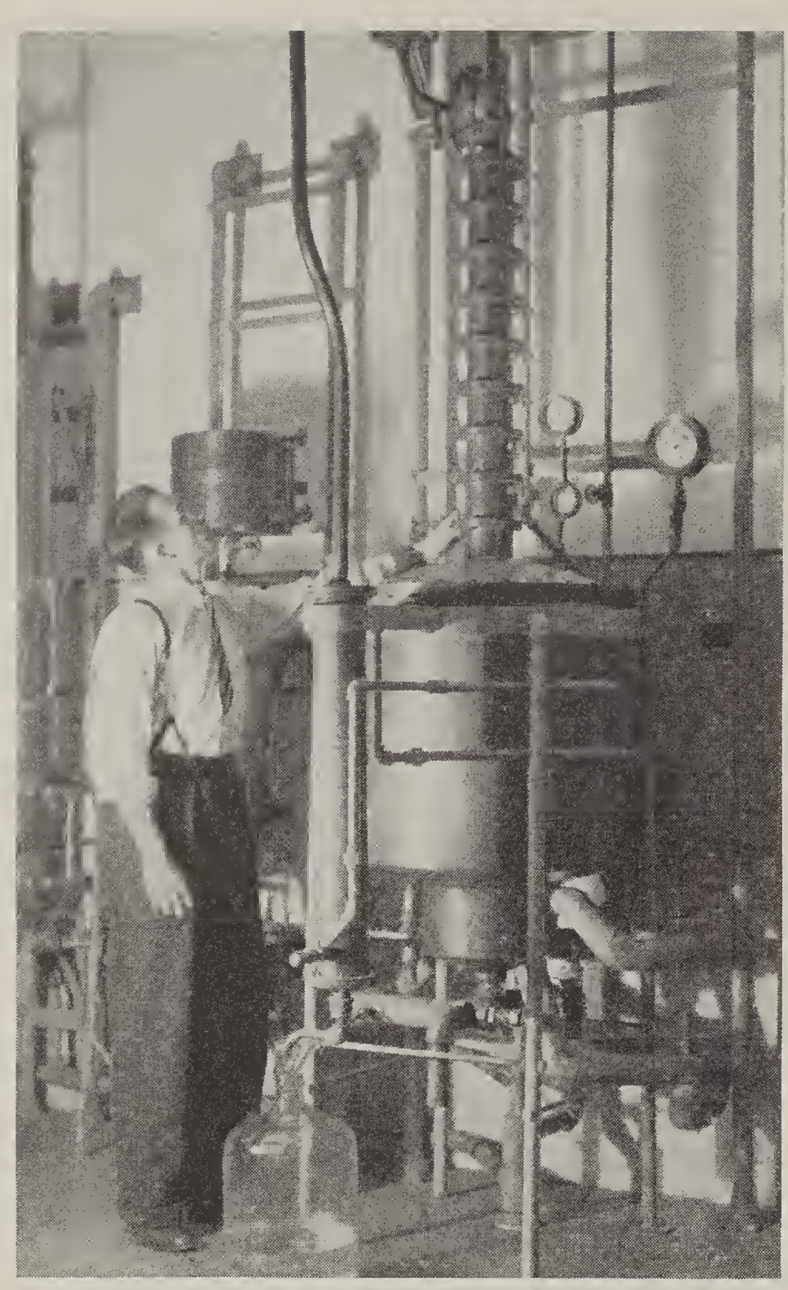

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Still for production of grain alcohol from wood.

dynamite can be transported and handled with a minimum of danger. Dynamite is largely used in blasting and land clearing; so it is possible to visualize this explosive, by volume largely white pine flour, being employed to remove the stumps of the very trees that contributed to its manufacture.

A large part of the remaining tonnage of wood flour is used in one of the newer industries, the plastics, again as a filler. Resinoid plastic products, particularly bakelite, often contain as much as 60 percent by weight of wood flour. Few users, perhaps, recognize a product of the forest in such things as molded radiator caps, radio dials, knobs, and panels, molded ashtrays, phonograph records, and many other articles of that class that are familiar to all. The relative cheapness of fillers as compared with the synthetic resin binders has reduced the cost of modern plastics and made them available to a very broad market. In this development wood flour has played an important part.

Ordinary adhesives such as starch, sodium silicate, or glue are also used with wood flour to form preparations that are molded into a great number of other products, such as doll heads, picture frames, and brush backs. Certain types of floor tiling are mixtures of wood flour, sawdust, and cements of various kinds.

Sugar and Ethyl Alcohol.

Certain European countries now augment their precarious food supplies by the production of edible sugar from wood. In cruder form, stock feed is produced, which is a roundabout way of preparing wood for human consumption as milk or meat. In countries where the supply of carbohydrates is ample, there is no real necessity of going to the forests for food, but the possibility at least exists in case of need; moreover, the process now furnishing sugar in Europe can be made the basis of other useful products.

It was pointed out earlier that nature makes cellulose by joining together molecules of glucose, the kind of sugar that is present in corn sirup. To recover the component sugar requires proper means of breaking up the cellulose molecule. The process is called hydrolysis, which means the splitting of the molecule by adding water chemically. By suitable processes of applying mineral acids to fine material such as chips or sawdust, most of the cellulose and materials related to cellulose in the wood can be converted into sugars, which can be used as food.

On the whole, however, a more promising use for these sugars seems to be their conversion into alcohol for use by industry. Fermentation by yeast produces from them ethyl alcohol—not wood alcohol, but exactly the same kind that is obtained by fermenting molasses, grain, or fruits. The process has assumed considerable importance in Europe; the products include both alcohol and a preparation of the yeast itself, high in nutritive value, which is used as feed for dairy cows. Alcohol can likewise be obtained by fermentation of the waste liquor discharged in the sulphite pulping process—a process that involves hydrolysis of part of the wood and which produces a liquor containing considerable quantities of sugar. Yeast fermentation of the liquor is now standard practice in most of the sulphite mills of Germany.

Xylose, one of the least resistant of the substances associated with cellulose, is partly converted in the course of acid cooking processes into the chemical called furfural, which escapes with the steam. Until a few years ago furfural was a laboratory curiosity, but it is now produced in tank-car lots from oat hulls. It has become very important in chemical industry as a solvent and intermediate reagent. Under suitable

conditions it could be recovered as one of the products of wood hydrolysis.

The lignin and unhydrolyzed cellulose, with other decomposed solid materials, are left as a residue after hydrolysis, their character and quantity determined by the severity of the cooking. The residue can provide the basis of a fairly nutritious roughage for stock feeding. Its technical use, however, has turned out to be more interesting, since it furnishes the raw material of the wood plastic referred to in a preceding section. By adding a small amount of other chemicals, including furfural obtainable at least in part from the cooking process, a molding compound is made that can be formed under high temperature and pressure into a hard, dense plastic of good strength and pleasing surface quality, at low cost. Thus from wood may be obtained food, forage, alcohol, and a serviceable plastic material as the result of one and the same conversion process—hydrolysis.

Products of Cellulose Fermentation.

The conversion of cellulose into sugar and the fermentation of the latter into alcohol by yeast, as described above, is a somewhat indirect procedure. But a moment's thought will show that there must be in nature living organisms capable of breaking down the constituents of wood directly, for not only does wood decay in the forest but it furnishes full nutriment to some forms of animal life. Patiently, therefore, scientists have studied the action of micro-organisms of various types on wood chips and wood pulp.

The action of the micro-organisms (bacteria) thus far isolated is principally on cellulose. The products of the fermentations are varied. Some organisms generate acetic, lactic, butyric, and other acids. Others produce alcohols of more or less complex structure, some of which may prove commercially useful. Rarely does a fermentation produce a single substance; for the most part distillations and purifications are necessary to isolate the valuable materials. But, with wood wastes as a potential raw material and with agents such as micro-organisms capable of reproducing themselves to an enormous degree, these processes hold much promise.

Products of Hardwood Distillation.

Wood distillation is among the oldest of industries, and charcoal was its earliest product. The use of charcoal as fuel in the heating appliances of the ancients is amply described, but its first use predates all written history. Charcoal is the carbonaceous residue left when wood is burned without enough air to insure its reduction to ashes. The ancients knew this principle well. Their practice was to pile wood in a heap, cover the pile with turf, and set it on fire. Charcoal and early metallurgy were inseparable. For centuries the principal aim in the production of charcoal was to make possible the winning of metals.

By the end of the eighteenth century the infant science of chemistry was inquiring into the products of incomplete combustion of wood, developing improved means of recovering the vapors generated, and otherwise giving attention to the transformation of the age-old industry of charcoal burning from its picturesque primitive form to a semblance of modern industry. It was found that more and better charcoal could be obtained and vapor-condensing devices could be used more efficiently if the wood were heated in a closed chamber. Throughout the nineteenth and into the twentieth century the development of wood distillation and vapor recovery installations went forward—from the brick kiln, or beehive, to the round metal retort, to the large-capacity steel ovens of today. While the production of charcoal remains a chief pillar of the industry, chemists have isolated more than 60 individual chemical compounds from the vapors evolved in distillation of hardwoods.

Not all of these are worth purifying or present in sufficient amount to be valuable. But the industry in the United States in 1935 produced, in addition to 20

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The residue of wood after hydrolysis can be used as the basis of a food for cattle.

million bushels of charcoal and large quantities of wood tar, more than 4 million gallons of crude methanol (wood alcohol), 25,000 tons of acetate of lime, and the equivalent of 10,000 tons more in the form of acetic acid and related chemicals. Its products were valued altogether at more than 7 million dollars. Improved metallurgical methods in the iron and steel industry since 1905 have progressively reduced the demand for charcoal, and the recent introduction of synthetic methanol and synthetic acetic acid has seriously narrowed the market for both of these products from wood. Acetone from wood, formerly of high importance, has now been completely displaced by acetone from fermentation and synthetic processes. Nevertheless the wood-distillation industry survives and, through improved general efficiency of refining methods, shows promise of retaining a relatively important position.[2]

M3265F

Wood distillation affords a use for cull trees, limbs, tops, and other material not suitable for lumber.

The interest of foresters in the distillation of wood lies in the fact that this is one of the few industries not concerned with either large size or superior quality in the wood it consumes. It affords a use for cull trees, limbs and tops, stumps, thinnings, and mill wastes not marketable as timber or pulpwood. Its expansion or decline will therefore have a considerable bearing on forest economics in regions where it operates or might operate.

[2] Among softwoods or coniferous woods, southern pines are the only ones distilled in any considerable amount. Their distillation products will be considered in the next section, under the heading of Naval Stores.

Seasonal Crops and Extractive Materials

WOOD is by far the most important product of the forest, and we have seen how it is used in many primary or converted forms. But the forests furnish many other materials that contribute to our material abundance. A special advantage of the products that remain to be enumerated is that they are, for the most part, an annual crop or harvest; year after year the forests can continue to produce them, until finally the mature trees themselves are harvested to make way for the next timber crop.

Naval Stores.

Outstanding in value among crops from the living forest is the harvest of naval stores in the Southeastern States, which yields important industrial raw materials worth from 40 to 50 million dollars a year. The term "naval stores" is a relic of earlier days when pitch and tar from the pines were indispensable for calking the seams and lubricating the ropes of wooden sailing vessels. Today it is simply a trade name for turpentine and rosin as produced from the southern pines.

The American naval stores industry developed in the virgin stands of longleaf pine in Virginia and North Carolina and was a fruitful source of income for colonial enterprise. The cutting of the longleaf over the whole South has finally localized the industry principally in Georgia and Florida and, to a less extent, in Mississippi, Alabama, Louisiana, and South Carolina.[3]

Twenty-five years ago, when virgin stands of southern pine were visibly approaching exhaustion, the naval stores industry was given over to early oblivion by many foresters. But nature refuted the prophets. The longleaf reproduced its kind and established thriving young stands. Slash pine, an excellent species for turpentining, the value of which had not been fully appreciated, showed great vigor in occupying cut-over lands, often replacing stands of the original longleaf. The turpentining of second-growth trees proved successful, and the result is that today the naval stores industry is accepted as permanent. Far from entering its last decline, it is steadily threatening overproduction of its commodities.

To a very large degree this reversal of outlook was aided by radical changes in working methods. In earlier days the operator cut a deep recess or box in the base of the tree to catch the flow of resin, generally with gross injury to the vitality of the tree and its resistance to windstorms. With the tool called a hack two downward sloping grooves were cut so as to meet in a V above the box, embracing between them usually one-third or more of the circumference of the tree. Since the idea prevailed that the bigger the wound the more resin would exude, the grooves were cut wide and deep with heavy hacks. Periodically, successive large grooves were cut one above the other to renew the flow. Numbers of the trees died in the first year or two under this type of working. In later times, when the sawmill was following the turpentiner closely, the loss was considered to be repaid by timber value.

When second-growth timber began to be turpentined, however, matters changed. The small tree could not provide room for the box or withstand the weakening effect of the heavy chipping, and when it died there was little or no market for it. In the meantime a new system of working had been developed in which the resin was conducted by narrow metal gutters into a removable cup suspended on a nail below the exuding surface. No longer was it necessary to administer the terrific wound of boxing. Then research workers proved that as good a yield of resin could be obtained by making shallow, narrow cuts as by gouging wide and deep into the tree at each chipping. Smaller hacks came into use. As a result of the improved methods, which are being more and more widely adopted, trees can now be turpentined for many years and still remain in thrifty condition.

The crude resin (oleoresin or gum) when collected generally appears as a thick white or grayish, fine-grained mass of soft, sticky consistency. It has the characteristic odor of turpentine. The cups hold a quart or more and are emptied at intervals of 2 weeks to a month or longer, most frequently during the hot

[3] It is known that large stands of ponderosa pine in the West are capable, if need should arise, of producing satisfactory turpentine and rosin. Climatic factors, available labor supply, and transportation costs, however, at present confine the industry to the Southeast.

weather of midsummer. The collected oleoresin is separated by a simple distillation process into turpentine and rosin.

The collection of oleoresin and its distilling are conducted in operations often far away from towns, in small, self-contained communities. A trend is seen at present toward the centering of distilling and refining operations in larger units that will be more efficient in the handling of materials and preparation of products; but the chipping of the trees and the gathering of the resin will doubtless remain an unmechanized occupation giving employment to a large body of labor for years to come. Turpentining as now practiced must be regarded as a prime example of industry that thrives by utilizing the forest while maintaining its life and growth. It is the forest-crop idea at work and paying its way.

There was produced from the southern pine forests in 1937 about 500,000 barrels of gum turpentine of 50 gallons each and about 1,650,000 barrels of gum rosin of 420 pounds net weight. Conservative estimates indicate that half as much again can be produced and probably will be in the future. Under normal conditions about half of the crop is exported.

Narrower chipping lengthens the resin-producing life of the southern pines.

M20553F

Turpentine and rosin are produced in other ways besides wounding the tree. The stumps of yellow pine are rich in resin, and a large industry producing more than one-fifth of the total naval stores has been built up on this fact. From chipped and crushed stump wood

M20912F

A large part of the annual crop of turpentine and rosin is exported.

turpentine is steamed out and rosin dissolved out with a petroleum solvent. A complex mixture called pine oil is also obtained. Originally something of a problem from the utilization standpoint, this oil of agreeable odor now holds an important place in modern industry. It is used in the flotation process for the concentration of ores of copper, lead, zinc, and many other minerals, in the treatment of wool, cotton, and rayon fabrics before dyeing, in the devulcanization and reclaiming of rubber, in commercial laundering, and in the manufacture of soaps, insecticides, and disinfectants.

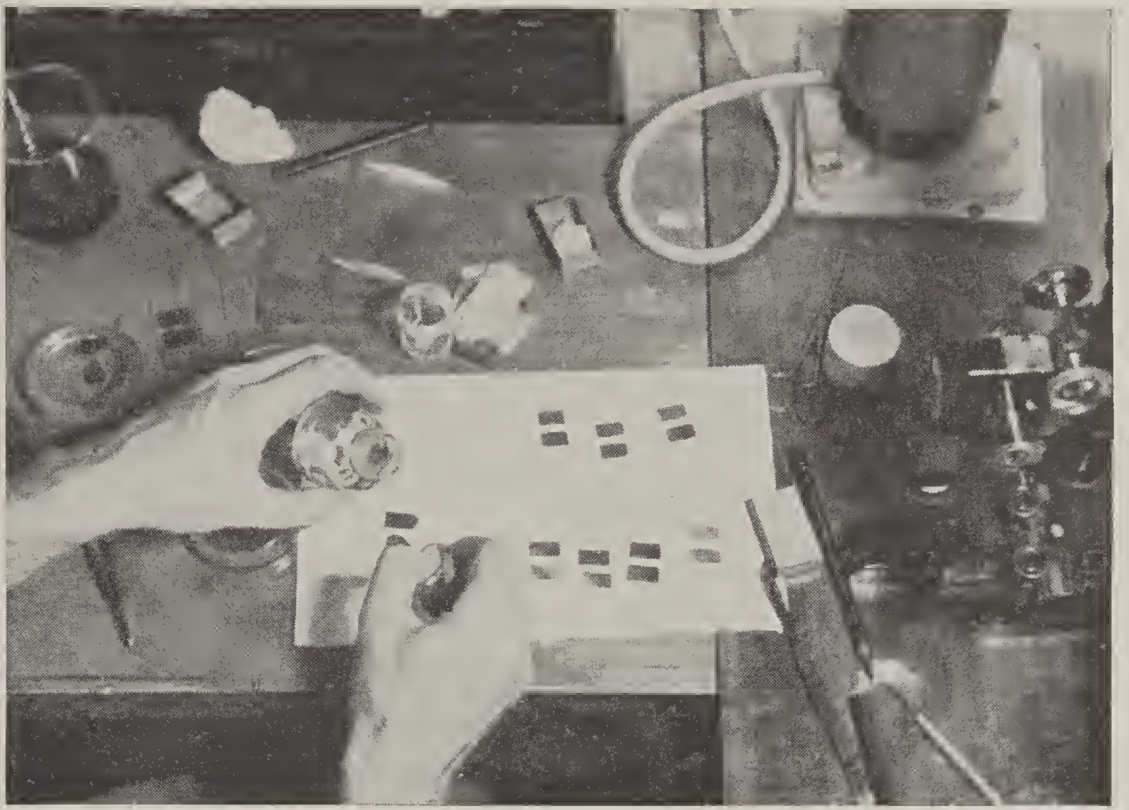
A relatively small production of turpentine and pine oil, along with tar and charcoal, results from the dry distillation of pine wood in retorts, in the same general manner as already described for hardwoods. Much turpentine is recovered as a byproduct in the sulphate process of pulping southern pine for paper manufacture. The pulping industry can also recover a soft form of rosin from the pines and in due time probably will do so.

Turpentine is used for the most part as a thinner for paint and varnish. A certain proportion, however, enters into various polishes, waxes, and pharmaceutical preparations. All synthetic camphor, of which 2 million pounds a year are produced in the United States, is made from turpentine. Most of this camphor is used in celluloid manufacture.

Rosin is one of the most versatile of industrial materials. It is present in a thousand articles of everyday use, yet seldom is its role detected. Its obvious and specific use as friction surfacing—for violin bows, machine belts, the boxing ring, or a slippery football—is

quite negligible in quantity consumption. Two million barrels of rosin has much larger tasks to fulfill in its year's work.

The paper industry uses about 360,000 barrels of rosin a year for size, a preparation that holds the surface fibers of paper in place, giving the sheet a firm finish, preventing the spreading out of writing ink on it, and reducing the pick-up of fiber by the type in printing. The varnish industry requires about 250,000 barrels of rosin a year. The market for rosin in this field has been greatly strengthened by the discovery that it can be combined with glycerin and other chemicals to form varnish resins far superior to rosin as such. The familiar yellow bar soap used in the kitchen and home laundry contains some 15 or 20 percent of suponified rosin. Tallow by itself makes a hard soap that is difficult to mill, but rosin soap is soft. Combined in the proper proportions, the two form a soap that has suitable properties both for manufacture and for domestic use. More rosin is consumed in soap than in varnish.



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Canada balsam has great usefulness as a transparent cement for lenses and as a mounting agent for microscopic slides.

A complete list of the uses of rosin in the products of modern industry would cover pages. Wherever an inexpensive adhesive or plastic is wanted, rosin is the first thought that comes to the mind of the manufacturer. Whether or not it will suit, rosin certainly will be tried. The tips of matches, shoe materials, linoleum, roofing, oils and greases, rubber manufactures, adhesive tapes, printer's ink—these are a few of the varied uses in which rosin has an important part. An obscure but essential service is performed in our huge packing plants where rosin lends its aid in dehairing the hog carcass.

Other Resins.

From blisters that form in the bark of the balsam fir comes Canada balsam, a resin that is important for one specific quality. Its refractive index is approximately the same as that of optical glass, so that it finds a high place of usefulness as a cement for fine lenses and a mounting agent for microscopic slides. Only a little is gathered in the United States. In prepared form it sells for as much as $40 per gallon. A substitute for it is the so-called Oregon balsam, obtained from the Douglas fir. About 500 barrels a year of this material is produced in Oregon and Washington at a price on the west coast of 75 cents to $1.50 per gallon. Refined for optical use it is supplied at a price of $8 or more per gallon.

The specific term "true balsam" is applied to such aromatic exudations as balsam of Peru and storax. Storax contains the fragrant cinnamic acid and related substances. Much of it comes from the Orient, but an equally good product is obtained by tapping the sweet gum of our South. The quantities handled commercially are relatively small. Storax is used in chewing gum, ointments, salves, and the like, but a more important use is as flavoring for chewing and smoking tobacco.

In the Sierra Nevada and in the foothills of the Coast Ranges grow two pines that yield resins of peculiar composition. These are the digger and the Jeffrey pines. In Civil War days, when the need for turpentine and rosin in the North became acute, Jeffrey pine was tapped along with ponderosa or western yellow pine, and the mixed resins were distilled. Not until a still exploded one day were suspicions aroused that the product being made might be different from the turpentine of commerce. The distinctive odor of the Jeffrey pine resin had been masked by the odor of ordinary turpentine coming from ponderosa resin. In the course of many years chemists found that the resin of the Jeffrey pine (and also that of the digger pine) gives not turpentine but heptane, an entirely different compound now known to be a constituent of gasoline.

For several years resin from Jeffrey pines was the source of the heptane used as a standard in testing the antiknock properties of gasoline. It has since been replaced by petroleum fractions or synthetic materials.

Maple Sugar.

Maple sugar and sirup are indigenous to North America. Early explorers found the Indians collecting the sweet sap and evaporating it in bark or earthen vessels by dropping hot stones into the liquid. In colonial times and the early years of the Republic, maple sugar was an important staple of diet. In the nineteenth century the rising volume and declining price of cane sugar displaced maple sugar as a necessity and made it properly appreciated as a delicacy. By 1875 the price of cane sugar had dropped substantially to its present level, and it became possible to make a cheaper sirup by blending. Today much sirup is sold with only enough genuine maple ingredient to give it flavor—sometimes as little as 10 or even 5 percent. Essences of various kinds in imitation of maple are obtainable. At least one imitation has been produced by borrowing from another tree. In 1882 a patent was granted to Josiah Daily, in Indiana, for such a preparation, a concentrated extract of hickory bark designated as "mapleine." The present product of that name utilizes no raw material from trees, but in some households a passable makeshift for maple sirup is still made by boiling together hickory bark and ordinary sugar.

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A Vermont maple orchard.

A northern climate is best for the production of maple sirup. In the period between winter and spring, when mild days are followed by freezing nights, the sugar maple yields its maximum flow of sweet sap. Little is known about the physiology of sap formation and movement in the tree, but it is apparent that the sugar-forming material has been stored through the summer and early fall as starch and that during the late fall and winter the starch is changed to sugar, which is soluble and can be carried in the sap to the places where new leaves are to develop and growth is to occur. By boring holes of proper size and depth, and not too many, it is possible to draw off a portion of the sugary solution with little or no damage to the tree's life processes. Trees are considered available for tapping on reaching the age of 35 or 40 years.

In the States of New York, Vermont, and Ohio, where production of maple sirup and sugar has been a regular business for many years, it is found that, on the average, 32 gallons of sap must be boiled down to make 1 gallon of standard sirup, which should weigh 11 pounds and on further evaporation should yield 8 pounds of soft or 7½ pounds of hard sugar. Stated in another way, 4 gallons or more of sap must be evaporated to get 1 pound of sugar. If an average amount of 2½ pounds of sugar is taken from a tree in a season, the sap required would be about 10 gallons per tree. In the case of a tree 15 inches in diameter, this would represent a loss of less than 7 percent of the tree's total store of sugar.

The sap as it flows from the trees usually contains from 2 to 4 percent of its weight in dissolved materials. Occasionally sap having as high as 6 percent of material in solution is reported, but 3 percent may be considered an average figure for all seasons and regions. The farmer who makes sirup has a very practical measure of the sweetness of the sap obtained in a given season; the smaller the sugar content, the greater the cordage of wood that must be burned to boil the sap to sirup. Of the dissolved materials in the sap, about 95 percent is a sugar, sucrose, exactly like cane sugar. The remainder consists of what are described as impurities, but they are impurities that give to the product its distinctive flavor and thereby add greatly to its value. The main basis of the maple flavor for years eluded chemical determination; but it was finally isolated, and some facts have been learned about its chemical structure. It turns out to be a substance resembling vanillin, the principal flavoring compound in vanilla;

but, just as synthetic vanillin itself fails to duplicate the overtones of flavor of the extract of vanilla beans, so the true maple flavor is blended of various subtle components and cannot be conveyed by any single ingredient. It will doubtless be many years before man duplicates in the laboratory the delicate shadings of flavor found in genuine maple sirup.

It is a curious fact that the maple flavor is not present in the natural sap but must be developed by boiling. Sap concentrated by freezing or by evaporation in vacuum pans does not possess the desired flavor; upon subsequent heating, however, the true maple flavor appears. Intensity of the flavor shows a definite tendency to increase in the more northerly producing areas. The mildest sirups are produced in Ohio and Pennsylvania, the strongest in northern Vermont and northeastern Quebec.

The value of maple sirup is determined by its grade according to color. Four grades, based on United States Department of Agriculture color standards, are generally recognized: Fancy (lightest in color), No. 1, No. 2, and No. 3 (darkest). Connoisseurs prize a light color and delicate flavor, but many persons living outside the producing regions show preference for the stronger, darker sirups. The two best grades of maple sirup and sugar are sold for the table and for confectioners' uses; the darker grades are purchased by blenders and by the tobacco industry. From 6 to 8 million pounds, mostly in the form of sirup, goes into the flavoring of pipe, cigarette, and chewing tobaccos.

The annual crop of maple products is entirely unpredictable, since it depends mainly on weather conditions during the few weeks when the sap is flowing. Shortages frequently occur. During 1936 about 12 million trees were tapped in the United States. From maple sap gathered and processed by farmers, more than 1 million pounds of sugar and about 2½ million gallons of sirup were made, paying a cash return to the farmer producers of nearly 4 million dollars. The output in 1936 was fairly typical of recent years, although production in the form of sugar seems to be still declining; it is today about one-half of what it was 10 years ago and one-twentieth what it was from 1850 to 1890. The United States does not produce enough maple sirup and sugar to supply its needs, the deficiency being made up by imports from Canada. Calculated as sugar, the imports average about 4 million pounds per year.

Honey.

Although no one would contend that honey is exclusively a forest product, it is nevertheless a fact that in forested regions bees derive a large amount of their wares from the blossoms of forest trees and shrubs. The characteristic flavors of many honeys are due to the admixture of nectars peculiar to a locality or region. The influence of certain forest trees in this respect is marked.

Basswood blossoms, for instance, are numerous and delicately scented; the honey has a flavor which is preferred by many. In some sections where the tree is still abundant this honey is marketed as a specialty. Likewise the gums and yellow poplar of the South and the eucalypti of the West contribute large quantities of honey of distinctive flavors. All the species mentioned have blossoms with large nectar cups which yield a high return to the bee's labor.

Certain bee colonies in Pennsylvania met with a remarkable misfortune some years ago during a dry summer. In the shortage of blossoms, they made their store of honey from a sweetish exudation from tamarack trees. The honey soon crystallized, and the bees, unable to feed upon it during the winter, fared very badly. The Bureau of Chemistry and Soils investigated the phenomenon and found that the unsuspecting insects had been collecting a very rare sugar, melezitose, and had thus provided for chemical science a large and accessible stock of this interesting material.

Tannins.

Hides of animals have given service to primitive man as clothing or footgear since the dawn of time;

The lordly chestnut, now deposed. Its wood is at present the most important domestic source of tannin, although incurable blight has all but eliminated the tree as a living species.

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their conversion into leather marks the transition from savagery to civilization. It is believed that the tanning of hides to preserve them and make them stronger and more pliable was practiced by the Chinese 3,000 years ago. Well-manufactured leather products of equally early date have been recovered from the tombs of Egypt. Historical records indicate that the barks of trees were a known source of tanning material among the ancients.

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Boles of western hemlock. The bark has a high tannin content, as yet little used.

Vegetable tanning extracts fall under the designation of "tannins," a term which applies to a large and complex group of chemical compounds occurring in almost all plants. Commercial tannins of today are derived from a number of forest sources, including bark, wood, roots, leaves, and even insect galls. Bark and wood remain the most important source. All tannins are bitter and astringent and have the property, in general, of combining with gelatin to make a solid, insoluble substance. It is this property that is used in making leather. When rawhide is soaked in a solution of tannin, the so-called collagen, similar to gelatin, that is contained in the hide combines with the tannin. The insoluble substance thus formed gives to leather its desirable wearing qualities, its durability, and its resistance to water.

Although science has developed chrome tanning and other mineral tanning methods by which a considerable volume of leathers is now made for various purposes, natural tannins still dominate the field. Especially are they required for the heavy leathers of shoe soles, harness, belting, and luggage. The following analysis, summarized from census statistics, indicates the relative importance of crude and extracted natural tanning materials in United States consumption in 1923; comparable figures for later years are not available.

Of our principal domestic sources, chestnut, hemlock, and oak, some 30 million pounds were used as solid extract, 302 million pounds as liquid extract, and nearly 1 billion pounds as wood or bark. Of materials imported from abroad, about 100 million pounds were used as solid extract, 105 million as liquid, and 110 million as bark or other crudes. In other words, approximately 537 million pounds of extracts were consumed—of which 205 million were from imported materials—together with more than a billion pounds of wood, bark, and other crudes, of which the great bulk was produced in the United States. Reducing these figures to the basis of actual tannin, the Nation's consumption of tannin from all sources for that year may be set at 300 million pounds. A decline in consumption, however, has been in evidence for a number of years. On the same basis it is estimated that at present about 230 million pounds are being used annually, valued at approximately 10 million dollars.

In the major tragedy of the destruction of the American chestnut by blight, the tanning industry offers some compensation as a heavy user of the blighted trees. Although the wood is, in general, too low in tannin content to be used in crude form as a source of tanning liquor, an efficient extraction process has been developed that has made chestnut the most important of all domestic tannin species. The extract is now being produced to the extent of 300 million pounds or more a year, and represents a considerable salvage of trees killed by the blight. Since there is no known remedy for the disease, rapid utilization of chestnut is economically desirable for the few years that the blight-killed trees remain standing.

The barks of chestnut oak and western tan oak are important domestic sources of tannin, yielding about

10 million pounds of extract annually and a large tonnage in crude form. The bark of the eastern hemlock was formerly the country's main reliance for tanning material, and it is still used as a crude, although the stand has been greatly depleted. Some sumac leaves are harvested in this country for tanning uses, but most of the sumac is imported, along with quebracho wood and extract, mangrove bark, and an array of other foreign materials that are contributing heavily to our requirements.

There is little doubt that the United States could be entirely self-supporting in tannin materials if available resources were utilized. The barks of most conifers are rich in tannins. The bark that is removed and burned at pulping mills alone could furnish more tannin than is now used. But leathers are special products. Their color, texture, and quality are a direct reflection of the kinds and combinations of tannins used. The fact that a bark contains tannin is no technical guarantee that it will make a grade of leather that the trade demands, desirable as that event might be. Much work lies ahead for the tanner and the industrial chemist before such a situation can come about. A case in point is western hemlock, the bark of which has a high tannin content. It is a relatively abundant species and is being increasingly used for lumber and paper making. The bark, however, has not yet found wide acceptance in the tanning of leather. Both scientists and the tanning industry are at work on the problem of its satisfactory utilization, since it is the material readiest at hand to supply domestic needs on a large scale.

Dyestuffs.

Before organic chemistry produced all the colors of the rainbow from coal tar and made synthetic dyes cheap and brilliant, all dyestuffs came from plants, or, in a few cases, from insects and shellfish. Long and toilsome voyages were made for cochineal, indigo, dye woods, and the colored fabrics of the Levant. To pioneer Americans, bright color was an exotic luxury. For the most part, they utilized the soberer hues of forest materials extracted at home. "Butternut jeans" typified the use of butternut hulls for their dyestuff content. In the Ohio Valley and elsewhere the leaves of the abundant coffee tree (*Gymnocladus dioicus*) were used as a source of yellow and green dyes. This tree was found from central New York southwestward to Arkansas and Nebraska. Its bark was used as a substitute for soap and its seeds for coffee, while its wood was made into furniture and a variety of domestic articles. Its multiplicity of uses in fact caused the present relative scarcity of a species once rated as very important.

Further toward the southwest, the wood of the Osage-orange (*Toxylon pomiferum*) was the source of a greenish-yellow dye. This tree furnished Indians with a superior wood for their bows. It was accordingly called bois d' arc by the French settlers, a name modified in American pronunciation to "bodarc" and still commonly used by those familiar with the species. In some sections it is known as the "hedge apple" or "mock orange."

The pigment contained in the wood is practically identical with that of the fustic imported from Mexico and Central America. During the World War, when imports of all kinds became an uncertain quantity, the use of the dye from Osage-orange or bois d' arc became industrially important. Much was produced, and many an American soldier wore olive drab dyed with the same wood extract that his forebears had used for their homespuns. After the war the revival of imports, but especially the growth of American chemical industry, caused this recreated dye production to languish.

Today there is produced annually about 400 barrels of the concentrated extract, worth in the neighborhood of $20,000. It is used mostly in dyeing leathers, but some is still used in textiles. While the dye can hardly be expected to occupy an important position again, there is the satisfaction of knowing that enough of the wood is growing to meet large demands in case of need.

A valuable dye is still prepared from the bark of the black oak (*Quercus velutina*), which occurs in the Appalachians and Middle Atlantic States. This brownish-yellow extract, known as quercitron, is used in the dyeing of textiles and also, to a minor extent, in tanning. Its annual production is more than 2 million pounds, worth about $75,000.

A host of natural dyes from forest trees are still used in home or handicraft industries. Many of them were tested by the Bureau of Home Economics, and the results are embodied in United States Department of Agriculture Miscellaneous Publication 230, Home Dyeing with Natural Dyes. The colors imparted are mostly browns and tans; with proper methods grays, greens, oranges, and yellows are also obtainable. The list of materials includes the wood of Osage-orange; the barks of yellow birch, cascara, western hemlock, hickory, Norway maple, black oak, chestnut oak, northern red oak, white oak, sassafras root, black gum, tupelo gum, and black walnut; the leaves of yellow

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A young native pecan grove. Other trees have been cut out, those that remain are budded to improved varieties.

birch and mountain-laurel; the berries of juniper and sumac; and the outer hulls of butternuts, hickory nuts, pecans, and black walnuts.

Nuts.

It is estimated that Americans consume about 50 million dollars' worth of nuts a year, exclusive of coconuts and peanuts.[4] Of the total quantity, probably somewhat less than one-half is imported. At a very rough estimate (since accurate figures on some domestic nuts are not available), about 10 million dollars' worth of our domestic production is represented by wild nuts, harvested from trees of the forest, wealth literally "picked up from the ground." The production here considered is strictly commercial, and does not include the large quantities of wild nuts gathered and consumed in homes, especially in rural communities. Neither does it take into account the important items of acorns and other mast foraged by hogs.

PECANS

To perhaps the majority of purchasers, "pecan" means the fancy large and thin-shelled varieties of that nut that are a specialty of the holiday trade. These are the cream of the crop, mostly the product of cultivated orchards of trees grown in nurseries from budded or grafted stock. The bulk of the pecan crop comes from wild trees growing in profusion in the river bottoms of Texas, Oklahoma, Louisiana, and other States south of the Ohio River. For example, in 1936 about 95 million pounds of pecans were produced, of which no less than 80 million pounds came from seedling or wild trees. The average annual production from 1928 to 1932 was 60 million pounds, of which only 13½ million pounds were from the improved varieties. In short, more than three-fourths of all pecans marketed are wild nuts.

The first announcement of the pecan to the world came from Texas. Cabeza de Vaca, after having been enslaved by the Indians (1528–36) relates the annual gathering of such nuts by his captors somewhere in the

Wild pecans (left) run about 90 to the pound; cultivated varieties (right), about 50 to the pound.

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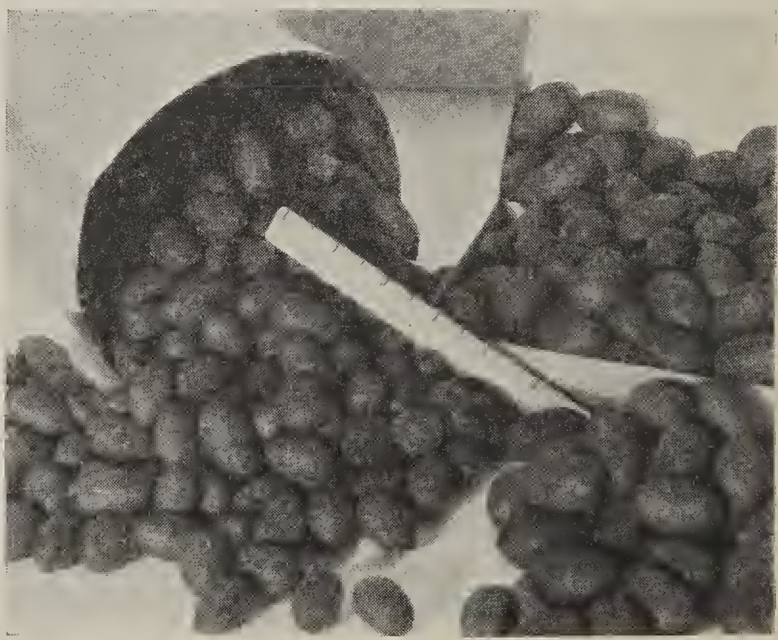

[4] Botanically, the peanut is a legume, not a nut.

coast country, probably to the west of Galveston Island. Penicault, in 1704, accompanied Bienville up the Mississippi. He described the nut, calling it pecan, which is an Illinois Indian word meaning a nut of any kind. George Washington, in 1794, wrote in his diary of the "peccane" or "Illinois nut."

Estimates of the number of wild pecan trees in Texas alone run all the way from 10 to 75 millions. Uncounted millions more are growing in other Southwestern States, mostly in valleys and river bottoms. Texas, Oklahoma, and Louisiana produce about 90 percent of the wild crop, but the nuts are harvested as far north as southern Indiana and Illinois.

The first commercial shipping and marketing of wild pecans, so far as known, was begun by Alex. Wooldert, a wholesale grocer of Texas, about 40 years ago. He was also the patentee of the original screw device for cracking pecans lengthwise, making it possible to extract most of the kernels in full halves free of bitter inside shell particles, and thus adding much to their value for all uses.

The cultivated varities of pecan have been developed from wild trees, which vary widely as to the size, quality, and quantity of the nuts they produce. Selected individual trees in the woods that produced large, thin-shelled nuts have been sold for large sums to nurserymen, who propagate the strain by grafting or budding. In this way several superior varieties have been introduced which furnish the higher class of stock for commercial pecan orchards.

Many famous pecan trees are described. Jumbo Hollis, a noted tree near Bend, San Saba County, Tex., is estimated to have been bearing nuts for more than 300 years. Its usual yield is reported to be from 300 to 600 pounds per year, and its record yield 1,015 pounds. According to data of the Agricultural and Mechanical College of Texas, the Hollis is one of the largest and heaviest pecan nuts known, averaging close to half an ounce each in weight. Another giant tree in Louisiana, south of Baton Rouge, is about 150 years old. It is 6 feet through the trunk, has a spread of 132 feet, and has borne as much as 1,600 pounds of nuts in a single season.

For the most part the wild trees are given no care, the only effort put forth being to club and gather the nuts. Great numbers of trees have been killed by scale and other diseases. Many wild groves, however, have been posted by the landowners, cleared of brush, and given varying degrees of cultivation, including in some cases the grafting of trees to improved varieties.

Much of the cultivated crop goes to the consumer as whole nuts. A large proportion of the wild crop is sold to cracking plants. Factory methods have greatly stimulated kernel production, so that a great volume of the meats is now available to bakers, confectioners, and purveyors of salted nuts.

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The black walnut is valued for both its wood and its nuts.

BLACK WALNUTS

Although by no means produced in such large quantities as the pecan, the nut of the native black walnut has achieved in recent years an important position in commerce. The production and use of this nut has suffered from two handicaps. One is that the wood of the tree has no peer among native species in sheer beauty and excellence for many uses; it has always been in great demand, so that the high returns from walnut lumber have caused a severe diminution in the stand of nut-bearing trees. The crop value of the species, however, is coming to be better understood. The walnut can be propagated rather easily, and in many sections of the Middle West and the South there has been consistent planting. Horticulturists have done some successful work in selecting strains for larger yields of nuts. The supply both of timber and nuts may be increasing, therefore, although no estimate of the situation is at present available.

The other and perhaps the primary difficulty about the black walnut from a commercial point of view is

that it is one of the hardest of all nuts to crack. The extraction of undivided half kernels from the average black walnut is an operation calling for both skill and luck. However, the reward in flavor and nutritive value of the meats, whether whole or broken, has caused the development of a considerable industry.

In 1900 the price for the small amounts of black walnut kernels then found on the market was from 6 to 8 cents per pound. By 1927 the price at retail had risen to 50 to 75 cents per pound. Nuts in the shell can be bought much cheaper, often for about 4 cents per pound. In 1936 one large jobber was reported as paying to producers 2.6 cents per pound for nuts and about 80 cents per pound for kernels. The latter figure, however, must have been exceptional, as recent figures compiled by the Tennessee Valley Authority showed that the general price paid for kernels to producers in that area was 15 to 25 cents per pound.

According to the best information, there has never been a market surplus of black walnut kernels. The demand, mostly from confectioners and ice-cream manufacturers, has increased steadily for more than 35 years, while the supply has been limited largely by the labor of cracking. It is said that a good cracker can earn 40 cents an hour. Some few cracking machines are in commercial use, but the extraction of the kernels remains for the most part a hand operation performed by the farm family as a spare-time enterprise. Since neither the gathering, curing, nor shelling of the nuts need involve any expense, the entire return may be counted as net profit.

The original trade, either for kernels or nuts, is between country merchants and the farmers. The largest collecting and distributing centers appear to be in New York, Baltimore, and Chicago. No valid estimate of the magnitude of the black walnut business is available, but isolated statements show clearly that it is not only large but fills a special need as a source of supplementary farm income.

The Tennessee Valley Authority figures referred to above indicate that the valley territory produces in a good year from 1,500,000 to 2,000,000 pounds of extracted kernels. Revenue to the inhabitants from this source evidently averages at least $250,000 a year, which is double the amount they received in 1935 from the sale of walnut timber. In 1936 a Tennessee firm handled 2½ million pounds of unshelled walnuts for which it paid $65,000, in addition to kernels for which it paid $20,000. A commercial plant in Virginia has sold 200,000 pounds of kernels since its operations started, 2½ years ago. Hundreds of thousands of pounds of kernels are shipped from concentration points in Arkansas, and Kentucky is also a large producer. The facts all tend to emphasize the economic importance of the black walnut crop in a market that is still far from saturation.

HICKORY NUTS

Hickory nuts are borne by about 30 recognized species of *Hicoria*, the same genus to which the pecan belongs. The nuts of the shagbark hickories have the largest kernels and rate best for human consumption. Many of the others are so small and thick shelled that they are practically worthless except as mast. Selected varieties are being improved by grafting.

Although hickory nuts appear in the market to some extent, most sales are purely local, and little or no information is available as to quantities. They often bring $3 to $4 per bushel.

BUTTERNUTS

A close relative of the black walnut, with the same type of hard, rough shell but oval in shape, the butternut is noted for its richly flavored, oily kernels. Although not an article of commerce to any great extent, it grows abundantly in some sections of the North and East, where large quantities are gathered for home consumption. Its kernels are used also as an ingredient of the maple-sugar confections marketed at many roadside stands in New England. By many the butternut is preferred to the black walnut both for the flavor and for the greater ease of extraction of its kernel.

CHESTNUTS

Most chestnuts now for sale are imported. The native chestnut was formerly found in all city markets but is becoming more and more rare as incurable blight steadily penetrates to the remotest stands of the species. The same fate has overtaken the near relative of the chestnut, the formerly abundant chinquapin of the South and East, to the regret of all who have prized the sweetness and flavor of its small but plump kernels.

BEECHNUTS

The very small size of the sharp-edged, three-sided beechnut and the dexterity required to extract the sweet kernel probably continue to prevent its becoming commercially important. Historically one of the most abundant nuts of the Northeast, it is still gathered in considerable quantities for home use. Varieties of beech are known that yield nuts up to 0.41 gram each in weight, or about 1,100 to the pound. It is possible that improved varieties might have commercial importance.

Thinly spread over thousands of square miles of the semiarid Southwest, a small pine tree, the piñon or *Pinus edulis*, does much to ease the hardships of existence for the Mexican and Indian population. Its wood provides building posts and fuel, and its nuts—borne in almost incredible profusion at about 7-year intervals and in smaller yields annually—furnish a very important item of food. They have in recent years become known to the East, and large quantities of the shelled kernels are now distributed through shops and vending machines.

Piñons are the only nuts produced by American coniferous species which are of any importance as an article of food or commerce. The nut of *Pinus edulis* is somewhat egg-shaped, half an inch or less in length, and, like all pine seeds, is borne between the scales of a cone. Its thin, brittle brown shell is filled with a rich kernel of distinctive and pleasing flavor.

Collection of the nuts by Indians and Mexicans usually means employment for the whole family. In 1936 a party of Navajos gathering the piñon were trapped by a heavy snow in the mountains of New Mexico, and difficulties overcome in their rescue became an exciting feature of daily news broadcasts. It is said, however, that incidents of this kind are by no means rare. The harvest begins as soon as the cones are opened by the first frosts and continues through the winter where not prevented by snow. The gatherers are occasionally rewarded by finding the hoards of squirrels and pack rats, which may yield 30 or 40 pounds of the finest nuts. But, for the most part, the nuts are picked from the ground or shaken from the trees and caught on spread tarpaulins. After cleaning, the nuts intended for market are often polished and roasted.

The total production is impossible to estimate with any degree of accuracy. Shipments of the nuts in 1921 are said to have amounted to 3 million pounds. Forest Service reports place the commercial crop in Arizona and New Mexico in 1936 at more than 6 million pounds and in 1937, a year of ordinary yield, at something between ½ million and 1 million pounds. The value of an average crop, counting both sales and local consumption, is roughly estimated at $500,000.

In Nevada, Utah, and southern California, another piñon, *Pinus monophylla*, or the singleleaf piñon, also bears great quantities of nuts. It is said that in California in former days Indians living west of the Sierras bartered acorns for piñon nuts gathered by those living east of the range. The traffic involved a journey of 20 days across elevations up to 12,500 feet. Two other piñons (*Pinus cembroides* and *P. parryana*) are nut-bearing species found at relatively high elevations in Arizona and southern California respectively.

Pharmaceuticals.

Early explorations in the forests of the Americas stored the apothecary shelves of the world with a host of new plant medicines. Some were of positive value,

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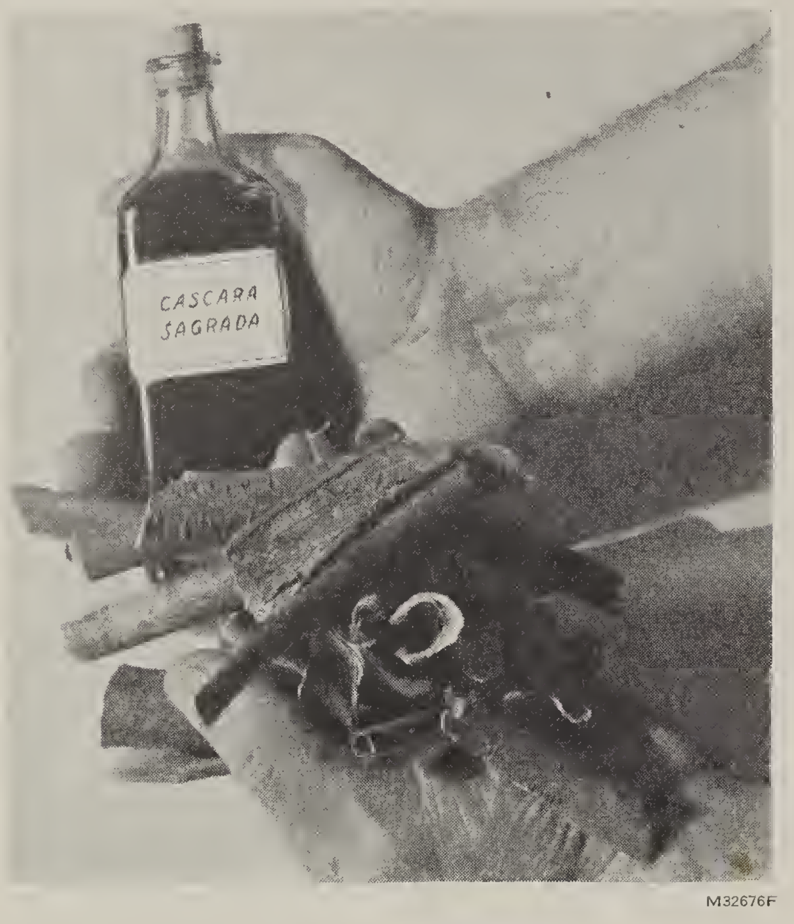
The piñon grows under semidesert conditions. Its abundant nuts are borne between the scales of the cones.

among which quinine bark and coca leaves, from South American trees, are outstanding. Others failed to justify the hopes they had awakened. In the United States a considerable lore of healing was taken over by pioneer settlers from the Indians. The whole forest and herbal pharmacopoeia has undergone a winnowing at the hands of medical science and experience in the time that has intervened. Some of the medicinal plants that were used have a place today in medical practice; others are relegated to folk-medicine and proprietary uses.

A principal producing territory for medicinal plants is the mountainous area of western North Carolina, eastern Tennessee and Kentucky, and southwestern Virginia. Here the northern and southern climates may be said to intermingle, providing a flora rich in variety. It is estimated that between 5,000 and 10,000 people in this region receive some $500,000 per year from the sale of crude drugs, including herbs as well as tree products.

No estimate can be attempted of the value of the business for the country as a whole, since no records are available. Some idea of it may be gained from export figures, though they probably represent only a minor



The bark of cascara is the source of a widely used elixir.

part. Exports of crude drugs in 1936 were $1,253,000, including herbs, both wild and cultivated, and ginseng root, in addition to tree products. Exports of essential oils, exclusive of citrus and peppermint oils, were about $820,000 a year from 1929 to 1936. It cannot be stated what proportion of these oils was of forest origin, but it was undoubtedly large.

Some forest-derived drugs are official in the United States Pharmacopoeia, which means that they are professionally recognized. Others are listed in the National Formulary, which admits drugs on the basis of wide use. Many others are articles of commerce in greater or less degree but are not listed in either compendium. As regards the various medicinals to be noticed here, it should be borne clearly in mind that no evaluation or recommendation of any item for any purpose of medication or health is intended. Such an evaluation falls entirely outside the scope of the presentation, which is intended only to suggest the variety of forest materials of this class that enter into trade.

CASCARA BARK

As the source of an elixir that has wide professional and proprietary use, cascara bark is one of the most important native drug materials. It is produced in Washington, Oregon, and northern California from the cascara tree (*Rhamnus purshiana*), which is known by at least 20 other names in the Northwest. Production is falling off because of the destruction of the trees and their increasing inaccessibility. The stripping of the bark as usually done kills the tree. Steps are being taken, however, toward the renewal of the stands by protection and planting.

The average tree yields about 25 pounds of bark. The bark is dried and aged before use, the well-aged qualities being the more valuable. In 1937, approximately 4 million pounds were shipped from the State of Washington alone. The total crop in past years has reached 7 million pounds. At an average price of 7 cents a pound to the gatherer, this represented an annual cash return of about half a million dollars.

SLIPPERY-ELM BARK

The inner bark of *Ulmus fulva*, slippery elm, is less in demand than formerly, although it still holds a place in the National Formulary. The time is not very far past when it was much in request for chewing and was even sold at retail for that purpose. It is said that another large market disappeared when the spitball was eliminated from professional baseball. A few years ago one Wisconsin dealer reported that he had made shipments of the bark aggregating 100,000 pounds.

SASSAFRAS ROOT

Bark from the root of *Sassafras variifolium* has a place in the formulary, although seldom prescribed in crude form. In the era of American exploration the most unbounded hopes were held for sassafras as a veritable cure-all. Cargoes of the root were delivered in England by expeditions licensed by Sir Walter Raleigh. In 1602 the price in England was 3 shillings a pound, representing a value of considerably more than 75 cents in money of today.

The "tea" made from the root is still enjoyed by many, both old and young—ostensibly for its health-giving value, but in many cases primarily for its flavor and aroma. In the spring the root is widely sold in the South at about 10 cents for a ½-pound bundle. Roots that give a pink color to the infusion are preferred.

SAW PALMETTO BERRIES

Palmettos are among the few representatives of the palm family in America. The palmetto here considered is a species of *Serenoa* of a shrubby type having no central stem, but often reaching a height of 10 feet or more. It is very abundant in Florida both in unmixed stands and as forest undergrowth. The

berries have listing in the formulary as a source of medicine.

The best berries comes from the east coast of Florida. It is said that an average of 40,000 pounds is gathered in one county annually, at an average price of 8 cents per pound to the producer. In the season 1935–36 about 90,000 pounds were sold at 5 cents per pound; in 1936–37 about 58,000 pounds were sold at 20 cents per pound.

WITCH HAZEL LEAVES

Hamamelis virginiana or witch hazel is a small tree, often a shrub, occurring widely in the eastern United States. Its leaves, listed in the National Formulary, are the source of the commonly used extract, which has mildly astringent properties. The therapeutic value of witch hazel is always questioned, but without effect on its popularity. The earliest record of its use is that of Cadwallader Colden, colonial Governor of New York. In 1743 he reported the treatment of injured Indians in their camps as follows: The patient was placed on a frame over a basin of water, under which a fire burned. In the hot water witch hazel leaves were stewed. An inverted funnel directed the vapors on the injured part.

OTHER MEDICINALS

Any detailed description of the truly miscellaneous forest materials that are still gathered and sold for drug purposes would fill pages. The following partial list of such materials will suggest their great diversity:

Arborvitae bark	Mountain-ash bark
Balm-of-Gilead buds [5]	Pine needles
Balsam tips and needles	Prickly-ash bark, northern [5]
Bayberry root, bark of	Prickly-ash berries [5]
Birch bark	Sassafras wood, chips
Black alder bark	Sassafras pith
Black ash bark	Sourwood leaves
Blackhaw root, bark of [5]	Sumac leaves
Blackhaw tree, bark of	Sumac berries
Black walnut bark	Sumac bark
Black walnut leaves	Tag alder bark
Black willow bark	Tamarack bark
Black willow buds	Wafer ash root, bark of
Butternut root, bark of	Wahoo root, bark of [5]
Butternut leaves	Wahoo tree, bark of
Canella bark	White ash bark
Chestnut leaves [5]	White oak bark
Cramp bark [5]	White pine bark [5]
Dogwood bark	Wild cherries, dried
Elder flowers [5]	Wild cherry bark [5] [6]
Elderberries	Wild cherry stems
Fringetree root, bark of [5]	Wild plum bark
Hickory bark	Witch hazel bark

[5] Listed in National Formulary.

[6] Listed in United States Pharmacopoeia.

Volatile or Essential Oils.

Volatile or essential oils are aromatic substances derived by distillation or otherwise from crude plant materials. They are obtained from leaves, roots, barks, and wood, as well as from many whole herbs, and are as diverse in chemical characteristics as their parent materials.

Dozens of oils from American forest trees have been prepared and analyzed, but few have become commercially important. Two oils from conifer leaves, produced in limited quantity, are given separate notice in the paragraphs following. The potential production of conifer-leaf oils is of staggering proportions; but although attractive industries in the mass utilization of leaves from thinnings and logging wastes can be planned on paper, there has not yet been sound economic justification for their establishment in reality.

Oil of cedar leaf is derived principally from *Thuja occidentalis*, the well-known northern white cedar or arborvitae; oil of similar or identical properties is obtainable from leaves of the closely related western red cedar (*T. plicata*). From 50,000 to 75,000 pounds a year are produced by farmers and small distillers in Vermont and upper New York. The price to the producer ranges from 35 to 75 cents per pound. Although the true oil is supposed to come from white cedar, other species are distilled, so that the oil of the trade is usually a mixture. It is used in insecticides and liniments.

Oil of hemlock and spruce needles is the second leaf extractive deserving separate mention. It is obtained from *Tsuga canadensis*, the eastern hemlock, and *Picea glauca*, white spruce. The needles of these species are mixed in various proportions in distillation, and the needles of other spruces are often mixed with them; the product is therefore not strictly uniform. The distillation is conducted mostly by farmers in Vermont, Massachusetts, and northern New York, where the production is now estimated at about 5,000 pounds annually at a price of about $1.10 per pound. In 1916 the production was probably 8 to 10 times as much. The oils are used as perfume in greases and shoe blackings; also in liniments and other medicinal preparations.

Southern cedarwood oil is obtained from the wood of *Juniperus virginiana* or eastern red cedar. The species is of greatest commercial importance in its southern range. Formerly the oil was entirely a by-product from the distillation with steam of milling waste. At least one distiller, however, has bought wood especially for distillation. The red heartwood

contains the oil. It carries the odor of the wood and is used in various ways as a moth repellant. It finds use also in the soap industry and as a mask for other odors in disinfectants and insecticides. An important scientific use is as an immersion oil for microscopes. One large American dealer estimates production to be in excess of 500,000 pounds a year. The present price is about 25 cents per pound.

Sawdust from the manufacture of red cedar lumber also has some sale as a moth repellant and as an incense material.

Oregon cedarwood oil is a comparatively new product. It is distilled from the wood of *Chamaecyparis lawsoniana*, the Port Orford cedar. Although chemically different from the oil of red cedar, it has similar insect-repellant properties and the price is slightly higher. The production is not known with any certainty.

Oil of sassafras is obtained from the root of *Sassafras variifolium*, the common sassafras. The industry was formerly of much greater importance than now. In 1919, about 194,000 pounds of oil were produced, worth $158,000, whereas in 1936 the production was only some 20,000 pounds. The price has ranged from 75 cents to $1.25 per pound. Sassafras oil is used for flavoring, aromatic, and deodorant purposes, but the competition of synthetics and of other oils containing the principal ingredient, safrol, has curtailed the market. Production is by small distillers in Maryland and Virginia. It could be expanded greatly throughout the range of sassafras if demand warranted.

Oil of sweet birch is produced in New England and the Middle Atlantic States and in the mountains of North Carolina and southwestern Virginia from the bark of *Betula lenta*, the sweet birch or cherry birch, that occurs from southern Maine southward through the Appalachians and westward into Michigan. The northern oil commands a price of $3.60 to $3.75 per pound at present, as compared with $1.65 to $2 per pound for southern oil. During the World War oil of sweet birch sold for $6 to $8 per pound. Chemically it is very similar to oil of wintergreen, for which it is substituted in flavoring. Stripping of the bark is usually carelessly performed so that the tree dies, although if it were properly done the harvest of bark could be repeatedly obtained. The oil can also be extracted from twigs, but to what extent the process is economically practicable is not known.

Christmas Trees and Greenery.

Not only is the supplying of Christmas trees to the families of the United States a large business, but with good management it should be a permanent source of income to forest dwellers. Christmas trees are, in the main, forest seedlings. Their removal in proper number need not cause any shortage of growing stock. In many cases the young stand is actually so dense as to call for thinning in order to assure satisfactory growth of timber. The planting and growing of trees especially for the Christmas-tree market is also practiced—a form of forestry on a short rotation that has much to recommend it. In northern New England a large part of the production is from trees that have sprung up in pastures.

Spruce and balsam fir are the favorite Christmas trees of the North and East.

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Unfortunately, however, too many Christmas trees in the United States are taken from stands that are injured by removal of the young stock. While it is true that the industry provides a great amount of winter employment in the country and holiday cheer beyond value for the city, it should nevertheless be conducted with an eye to future business and with proper regard for timber possibilities.

It is estimated that 10 million Christmas trees are sold annually. At an average price of 10 cents each to the producer, their contribution to rural income may be reckoned at 1 million dollars.

A vast and undetermined volume of decorative foliage and boughs also moves to the Christmas market. Sprigs of conifers from nearly all parts of the country, magnolia and mistletoe from the South, holly and mountain-laurel from the East, Christmasberry, Oregon hollygrape, and salal from the west coast—all go to make up a veritable flood of greenery at holiday time. Woods ferns, huckleberry, lycopodium, leucothoe, and galax add largely to the total. It is estimated that in the eight counties of the Eastern Shore of Maryland 10,000 people engage in the annual harvest of holly, for which they receive $150,000. The Forest Conservation Commission of Delaware reported in 1927 that the holly crop in that State had an annual value of about $400,000, of which $100,000 was expended for labor.

Fruits.

The fruits of the forest were appreciated more in pioneer days than at present. As the country became settled, cultivated horticultural species were introduced from the Old World and the labor of developing native fruits was largely avoided. Doubtless, also, much of value was thereby neglected. The wild crab apple, for example, growing in profusion and in many species over a very wide range, has never been cultivated for its fruit to any extent. Its possibilities of value are proved by the delicious jellies and butters made from it in many country households.

The many species of haws, wild cherries, and plums are valued locally and used to a large extent. At least 18 species of wild plums are native to the United States. Many of them form an important item of fresh and preserved fruit for the rural population. Some have been domesticated, and some variants from wild species have become thoroughly established as important cultivated varieties. The latter have been derived, for the most part, from the northern wild plum (*Prunus americana*) or the southern or Chickasaw plum (*P. angustifolia*). Horticulturists have found that our more important wild plums are hybrids and that the process of domestication has been one of selection among widely variable progeny.

The early settlers were more familiar with the serviceberry (*Amelanchier* spp.), usually called sarviceberry, than is the modern population. Its fruiting marked early summer and a supply of especially appreciated pies and jellies.

The papaw (*Asimina triloba*), closely akin to the West Indian custard apple, has something of the Tropics and something of the North American wilderness in its taste. When ripe it is a large, soft fruit of altogether distinctive aroma and flavor. Being indigenous throughout the central and eastern United States, there is little doubt that it could be successfully cultivated and selectively improved.

The fruit of the common persimmon (*Diospyrus virginiana*) is the butt of many jokes having their point in the astringent power of the unripe fruit. Captain John Smith bore early testimony to this quality when he wrote, "if it be not ripe, it will draw a man's mouth awrie with much torment." The bland sweetness of the persimmon when thoroughly ripened is equally widely acknowledged; nevertheless it is a fact that it is a fruit more or less slighted over much of its broad southern range.

Several causes have contributed to its neglect. One is that it is not supposed to ripen until "after frost"; since this is by no means necessarily true, much of the crop falls to the hogs. Another is that fruit knocked from the tree may be deceptively ripe-appearing and yet very unpleasant to eat, whereas the fruit that is thoroughly ripe is so soft that when it falls from a high tree it usually bursts, or at least suffers some penetration by dirt and litter. All told, the persimmon has jocular and plebeian associations which, added to the difficulty of getting up a persimmon-hunting expedition, have put it largely outside the serious attention of town dwellers.

On the other hand, in food value the persimmon is surpassed only by the date. The flavor of the ripe fruit is rich and in no degree inferior to that of the highly prized Japanese persimmon. Although cloying to some individuals, the taste is enjoyed by most of those who are familiar with it or have acquired it. In skillfully prepared puddings, breads, muffins, or cakes the persimmon is worthy of acceptance on any table. The pulp can be preserved in the home kitchen by the simple admixture of an equal volume of sugar, followed by gentle heating to expel the air.

Care in gathering and marketing the fruit should greatly enhance its popularity. At present it is marketed only locally and in small amounts. The development of superior strains offers further possibilities. The tree is admittedly difficult to transplant or to propagate by budding. Farmers' Bulletin 685, The Native Persimmon, gives helpful directions for these operations.

The native red mulberry (*Morus rubra*) provides a sweet fruit in abundance, which, however, has never gained a high rating for domestic use. The rather weak-flavored elderberry (*Sambucus* spp.), on the other hand, finds a place in home-made wines and, to a less

extent, in preserving. Products of the forest, although not of trees, are the blackberries, raspberries, wild strawberries, and grapes that abound in many sections, all of which contribute their share to nature's bounty in a good fruit year.

Miscellaneous.

Obviously, a complete description of miscellaneous uses of forest products by local populations might extend to great lengths. Only a few examples of more or less general interest need be mentioned here.

The wood of the western larch (*Larix occidentalis*) is noteworthy for its high content of a gummy carbohydrate called galactan. Especially rich in this substance are the butts and stumps, of which it is estimated that 30,000 cords a year could be assembled in Montana and Idaho alone. Commercial operations were undertaken some years ago to extract galactan from the wood and convert it into mucic acid. This substance, similar to tartaric acid, found use in baking powder and other products in which an edible acid was required. The industry is not operating at present but may be revived when conditions warrant.

The waxmyrtle tree (*Myrica cerifera*) is chiefly southern in range, reaching its largest size in sandy swamps of the Atlantic and Gulf coasts. The shrub bayberry (*M. carolinensis*) has a range from Nova Scotia to Florida and Texas. The small berries of both species are encrusted with a pale wax that can be separated in hot water. The recovered product is greenish in color and is known as bayberry wax or tallow. The commercial article of this name is obtained also from several foreign species. Bayberry wax has some applications in pharmacy, but its chief use, on account of its color and solidity, is in candles and ornamental waxwork. It is said to have been one of the first products shipped from North America by the French, and it was formerly a considerable article of commerce. Only about 40,000 pounds are now produced each year, mostly in Massachusetts and Rhode Island, bringing a return to the gatherer of 10 to 20 cents per pound. It is marketed principally in New York City. Jobbers' prices for the wax in 1937 were about 60 cents a pound.

Pine needles have been transformed into a soft padding material that is useful in upholstery. The process is simple: Boiling in alkali, washing, and carding. "Spanish" moss, the benign parasite of trees in the lower south, is also gathered in large quantities and used in furniture upholstery and low-cost mattresses.

Indians made much of their twine and rope from the fiber of basswood bark. This fiber is still used, locally, for the same purpose. In other sections strips of hickory bark are used for withes, chair bottoms, and the like. The familiar rustic furniture of bent willow, elm, hickory, and other woods affords further illustration of the use of forest materials in handicraft work.

Relative Value of Forest Crops

IN attempting to reckon the annual values returned by the forest to primary producers, it must be recognized that prices for crops of all kinds vary from year to year, and that the forest crop has been severely affected by the depression cycle both in price and in quantities produced. Furthermore, accurate statistics are lacking for a large group of minor products and some major ones as well. Any general figures presented must therefore be in the nature of estimates based on whatever statistics or partial information is available, preferably for years that may be regarded as normal rather than for years of lowest demand. With these reservations, the following listing will serve as an estimate of the relative value of various basic items of the domestic forest crop at the point of utilization or distribution; imports are not included:

Logs for lumber and other sawn products	$300,000,000
Fuel wood	240,000,000
Fence posts	80,000,000
Pulpwood	50,000,000
Veneer logs	20,000,000
Hewn ties	18,000,000
Poles	10,000,000
Piling	4,000,000
Distillation wood	3,000,000
Naval stores	40,000,000
Tanning materials	10,000,000
Nuts	5,000,000
Maple sirup and sugar	5,000,000
Christmas trees and greenery	2,000,000
Pharmaceuticals and oils	1,500,000

However rough the above estimates may be, every item has its economic meaning. An easy deduction from the figures is that wood itself far overshadows other tree crops in importance; in fact, wood in the several forms here listed has an assigned value more than 10 times that of all the rest, including naval stores. Some such relationship must doubtless continue to hold, but it does not bar the lesser products from consideration. Some of them are intricately woven into modern life and industry. All of them, even the humblest, deserve proper technical development for their contribution to forestry values and for the continued or increased income they may bring to workers.

With respect to the need for a more complete development of utilization values, forest products, both major and minor, stand in much the same case. The value of 300 million dollars tentatively assigned to the premier item of all, logs for lumber and sawed timber, reflects only a small part of the decline that has occurred in that class since the 1920's. While substantial gains are being registered in paper production and fiber conversion, they by no means compensate for losses sustained in construction, wood distillation, and other large uses.

The part that scientific research has to perform in maintaining and increasing the utility value of forest products and some of its accomplishments in that direction have been pointed out. Fundamental social and economic values are at stake in its work. Despite the untold riches that the United States has extracted from her forests, the processes of utilization have too generally been haphazard and inefficient. Through the diversification and improvement of products and their adaptation to the standards of the modern industrial age, the forest should remain among the greatest of the Nation's possessions in the future as it has been in the past.

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Ice Cream